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April 1996
NSRP 0465

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Square Butt Pipe Welding

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
Peterson Builders, Inc.

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U. S. DEPARTMENT OF THE NAVY
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NSRP 7-92-5

THE NATIONAL SHIPBUILDING
RESEARCH PROGRAM

SQUARE BUTT PIPE WELDING

A PROJECT BY
PUGET SOUND NAVAL SHIPYARD

FOR

THE WELDING PANEL
SP-7

FEBRUARY 1996
NSRP 7-92-5

SQUARE BUTT PIPE WELDING

A Project of

The National Shipbuilding Research Program

for

The Society of Naval Architects and Marine Engineers
Ship Production Committee
Welding Panel SP-7

Prepared By

PUGET SOUND NAVAL SHIPYARD
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NATIONAL SHIPBUILDING RESEARCH PROGRAM

SP7 - WELDING

Project Title: Square Butt Pipe Welding

Task Number: 7-92-5

Purchase Order Number: 9757-0031

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Final Report

Objective:

The main objective of this project was the development of welding techniques and procedures to economically weld fabricate pipe. X-ray quality full penetration square butt weld joints were expected. Significant cost savings can be achieved through the reduction in pipe fitting and welding man-hours by utilization of a saw cut square butt joint design. The investigation of the various weld techniques and joint configurations are detailed in this final report to the National Shipbuilding Research Program's SP-7 committee on Welding.

Background:

The square butt joint design (Figure 1) is a weld joint where the pipe is butted together without a bevel. This type of joint design is easily prepared without a machine or hand ground bevel.

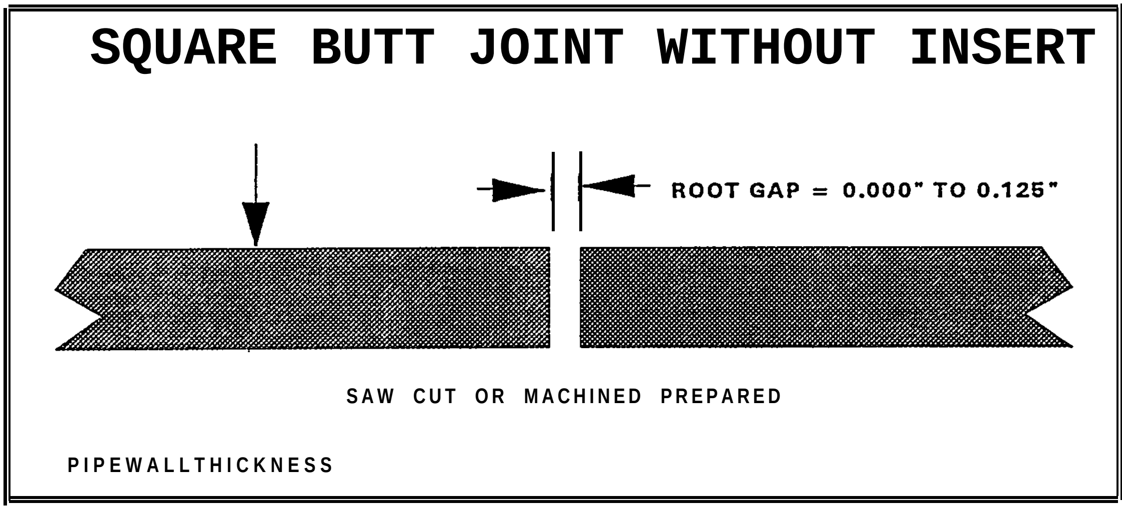


FIGURE 1

In thin wall tubing applications (< 0.125″ wall thickness) automatic orbital gas tungsten arc welding (GTAW) machines routinely weld squre butt joint tubing for a variety of commercial applications and materials. An example is Wellons in Sherwood, Oregon, a manufacturer of boilers and kilns. Wellons routinely welds plain carbon and stainless steel piping 1“ to 3“ OD with wall thickness up to 0.140″. Over 120,000 square butt joints have been welded using a Dimetrics Inc. “Centaur III, Portable Model 150 PTW” computer controlled orbital tube welding system with “Model 5000 Series Heads”. The pipe is single pass welded to meet the ASME Boiler and Pressure Vessel Code, Section III for low pressure piping. These pipe welds have controlled pipe wall thickness of plus or minus 0.003″ and square butt joint fit-up of 0.0 to 0.010″ gap. The welds are autogenous and a second manual filler pass is added only if excessive concavity is visually found. Mismatch of 25% wall thickness can be welded but an additional weld pass may be needed to fill concavity.

Norfolk Naval Shipyard has qualified up to 0.147″ wall thickness for GTAW on P-2 Copper Nickel piping single layer. Work by Puget Sound Naval Shipyard (PSNS), Welding Engineering Division successfully demonstrated six inch diameter, 0.250″ wall thickness square butt one pass welds with no filler material in the horizontal rolled position. This project was undertaken to increase the use of square butt welding for thicker wall pipe in the fixed position and to evaluate field welding.

Technical Approach:

Four base materials commonly used in Naval pipe applications were chosen for this project. They are carbon steel (S-l), 304 stainless steel (S-8), 90% 10% and 70% 30% copper nickel (s-34), and 70% 30% nickel copper (S-42, Monel) . TABLE I of MIL-STD-248 groups the base materials equivalents by “S” number. Pipe wall thickness from 0.072” class 700 copper nickel up to 0.438”, 3 inch schedule 160 stainless steel were weld tested. Three basic square butt weld joint designs were evaluated: square end without insert (see Figure 1), square end with insert (Grinell style) and a modified square end butt with a 45 degree V-groove for wall thickness 0.250” and greater (see Figure 2) . The weld test joints were prepared by machining or were used in the as saw cut condition. Root gaps up to 0.300” and mismatch up to 25 percent of the wall thickness were tested to evaluate fit-up tolerance effect on weldability.

Automatic and manual pipe welds were evaluated for square butt joint design. Automatic welding was performed with an Arc Machine Inc. (AMI) system on a Model 15 and 81 weld heads. Manual welding utilized a Miller Arc-Pak 350 with a Tig-Rig 2S controller and Digi-Meter 600 amperage and volt meter. Pulse arc and steady arc schedules were evaluated on both manual and automatic.

In addition to the above elements, three main weld variables were evaluated for successful thick square butt welds: 1) Pulse purge versus steady purge, 2) 95% Argon 5% Hydrogen versus 100 % Argon shielding gas, 3) Blunt tungsten electrode versus four to one tapered tungsten electrode.

After all evaluations of weld techniques for square butt pipe welding, weld procedures were developed for carbon steel, stainless steel and Monel. These procedures have been submitted to NAVSEA 03M2 for approval.

Test Results and Evaluations:

Manual:

Joint Design Evaluations

The initial evaluations and tests were conducted from July 1993 to July 1994. Three weld joint designs were manually weld evaluated on the four selected base materials; carbon steel, 304 stainless steel, 70% 30% Monel and 90% 10% and 70% 30% copper nickels. Figures 1 and 2 depict the typical joint designs used in these early trials. A fourth joint design, a self aligning modified square butt with 10 degree bevel was used successfully in place of the straight square butt (see Figure 3) . This 10 degree bevel joint design reduced mismatch and self aligned the

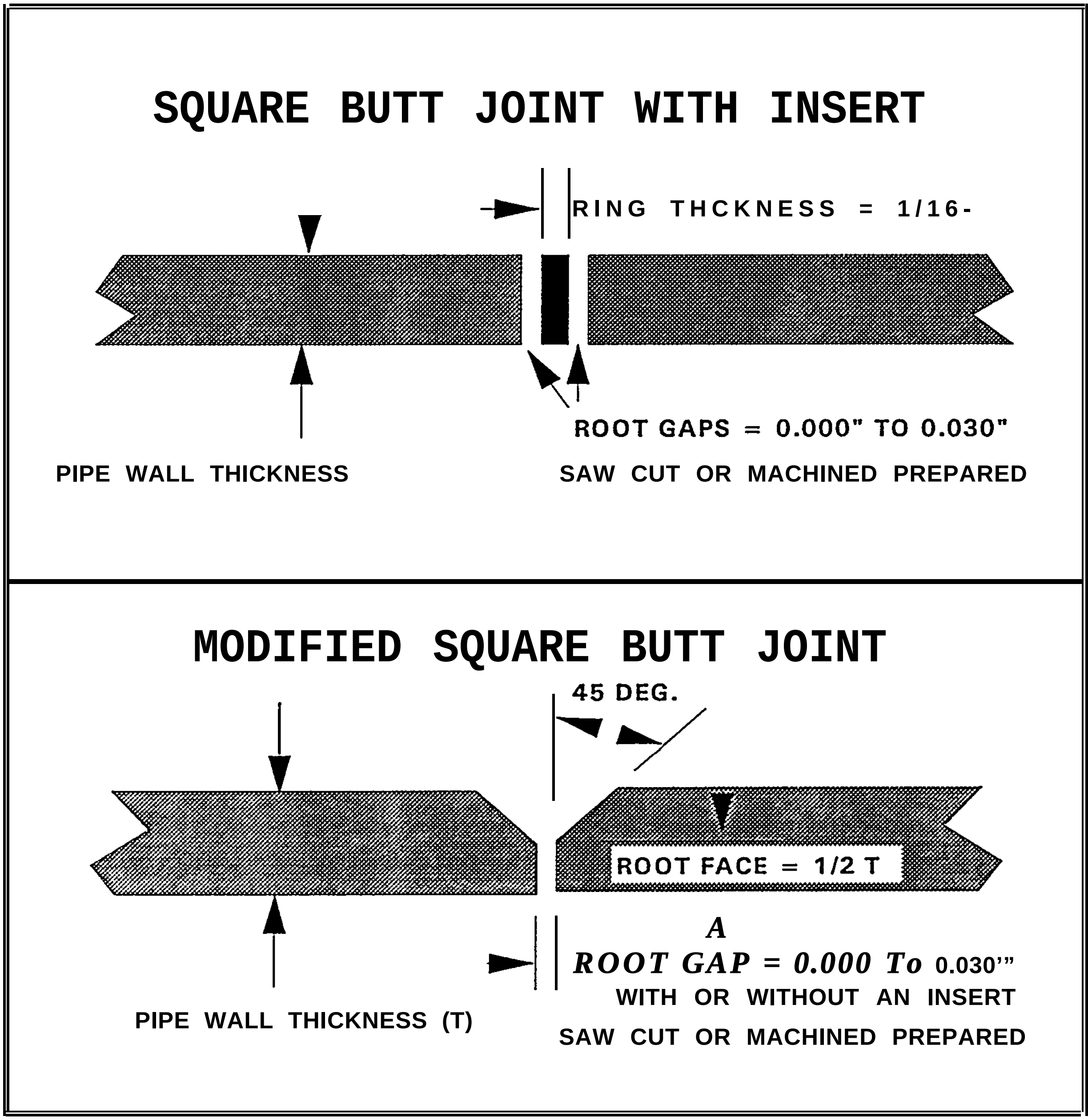


FIGURE 2

two pipe segments but was not pursued further in this study due to the need for machine preparation for this joint. Initial trials also showed no advantage in pipe wall weld penetration for: Machine preparation on straight square butt; Square butt with insert versus plain saw cut; or Deburred end preparation. An insert square end butt pipe wall weld penetration was the same as straight square end butt welds. For carbon steel and stainless steel maximum through wall thickness producing satisfactory internal weld contour was 4" inch schedule 40, 0.237" wall thickness.

10° SQUARE BUTT JOINT DESIGN

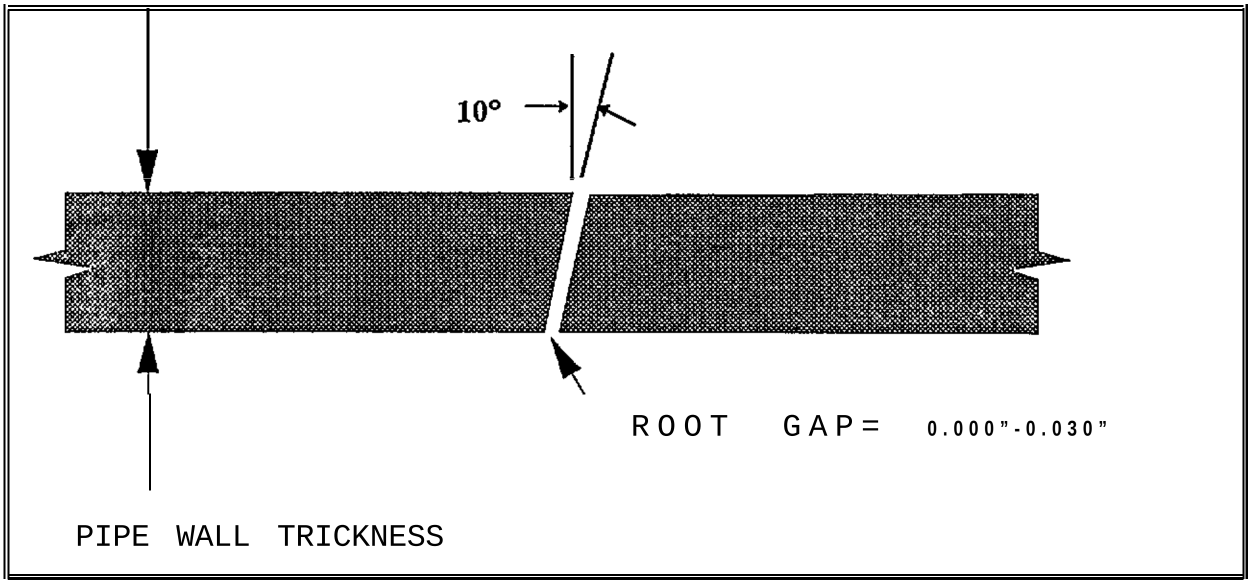


Figure 3

Ibis was true for all machined or saw prepped pipe, whether with a 10 degree bevel, a straight square end or a square butt with insert joint design. Pipe wall thicknesses above 0.250" require use of a bevel joint design (depicted at the bottom of Figure 2). For Monel, the maximum pipe wall thickness satisfactory both for visual and cross sectioning, was 2" schedule 40, 0.154" wall thickness. Through weld penetration up to 0.180" was possible on copper nickels, no cross sections were satisfactory due to fusion line porosity. This problem is discussed under material variations.

Single Pass Versus Two Pass Welds

The joint design used was found to affect the number of passes required to complete a weld. Square end machined joints with no gap and minimal mismatch needed only one pass to achieve satisfactory weld contour and X-ray satisfactory welds. Square end saw cut joints resulted in fit up end gaps and mismatch that required two pass welds to achieve satisfactory weld contour. This is a root pass with through wall fusion and a cover layer.

If properly fit-up square end pipe with an insert, machined or saw cut pipe weld joints required only one pass for satisfactory weld contour and X-ray quality. Minimal test work on square end with an oversized insert and the 10 degree bevel self aligning joint produced satisfactory single pass weld contours. Two passes were required on the thick wall bevel joints tested to fill in the bevel and provide sufficient weld reinforcement.

Based on the economics of the cost of manufacturing inserts, machining end preps versus weld time of two pass welds over one pass it was decided to concentrate further tests on two pass, saw cut and deburred joint design only. Also it was anticipated that most field welds would not fit up as closely as needed to guarantee satisfactory single pass finished welds. PSNS pipe weld applications are made to MIL-STD-278 which require two pass welds on high temperature and pressure weld joints. Though for some applications single pass welds may be sufficient, the direction for the balance of the program was directed to qualify MIL–STD–278 and MIL-STD-248 weld procedures.

Tungsten Shape

A 90 degree included angle blunt, tungsten electrode was found to enhance the depth of the weld pool penetration as compared to the 4 to 1 taper tungsten tip that is normally used for GTAW (see Figure 4). The fan shaped arc plasma produced by the 4 to 1 tapered tungsten is inclined to enlarge the size of the weld pool and diminish its depth of penetration. Concentration of the arc heat with the tapered tip requires a very short arc length, increasing the potential for the tungsten tip to come in contact with the weld pool. The shaft shaped arc plasma produced by the blunt tungsten tip was found to improve through wall fusion due to the more concentrated arc heat, without the necessity of an excessively short arc length.

TUNGSTEN TIP SHAPES

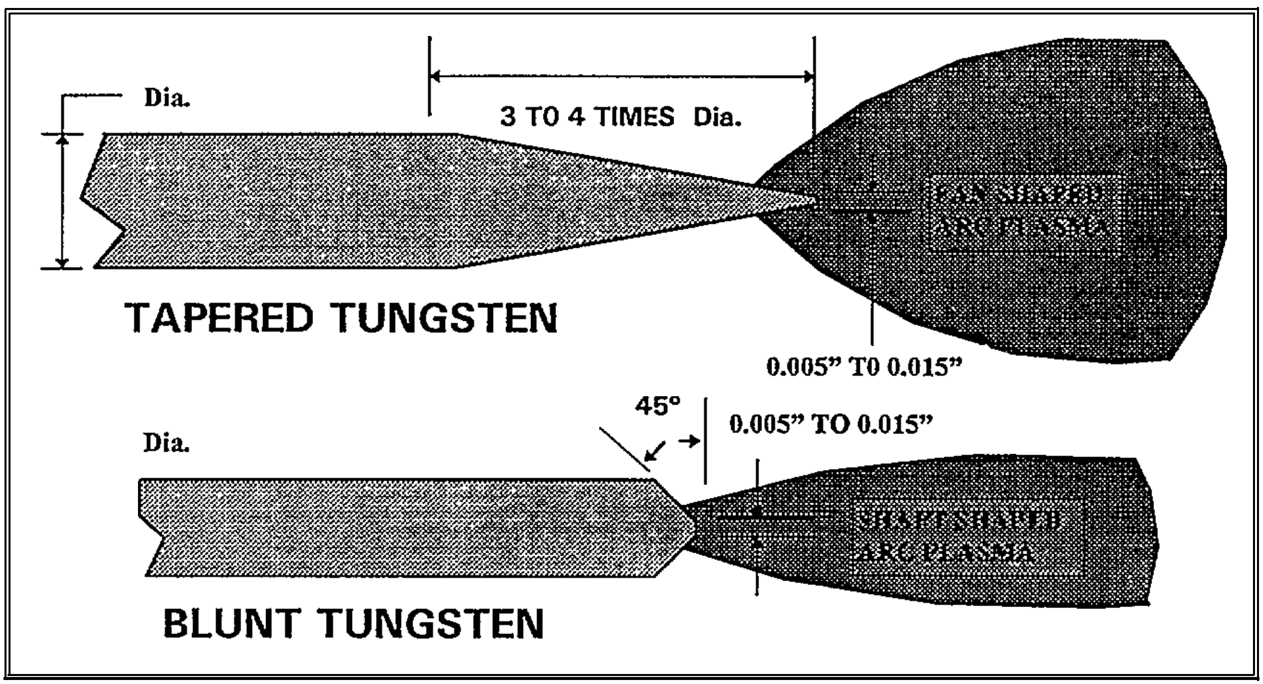


Figure 4

Shielding Gas

95% Argon with 5% Hydrogen was used as a torch shielding gas because of its capacity to improve the depth of weld pool penetration compared to 100% argon. It also intensified the heat of the arc so that lower amperages, 15 to 20 percent less than with 100% Argon, were needed to penetrate the same pipe wall thickness. This decreased amperage also reduced the heat input to the general weldment resulting in a smaller heat affected zone and more rapid cooling. Photograph 1 (see Attachment 23) compares the through stainless steel pipe wall fusion cross sections of 4 to 1 tapered tungsten using 100% Argon to blunt tungsten tip weld sections using 95% Argon with 5% Hydrogen, at various pipe wall thicknesses. The combined beneficial effects of blunt tungsten tip electrodes and 95% Argon with 5% Hydrogen produced a narrower, straighter weld root bead.

Maximum pipe wall thickness for carbon steel and stainless steel producing acceptable results using 100% Argon was 0.150”. The increased weld amperage required for greater wall thickness resulted in excessive heat buildup and produced unsatisfactory internal weld contour.

95% Argon with 5% Hydrogen improved the weld puddle properties of copper nickel and nickel copper, making their welds more like stainless steel and produce acceptable weldments to a greater depth or larger wall thicknesses. However 95% Argon with 5% Hydrogen shield gas did result in fusion line porosity in copper nickel welded pipe joints.

Pulse Purge

When welding with steady current GTAW, a purge with an inert atmosphere is necessary for full wall thickness root fusion. The quality of the purge gas on the root face of the molten pool is a key element in producing a satisfactory pipe butt weld. Purge quality is determined by the purity of the purge gas, void of oxygen and moisture, and control of internal pressure is accomplished by proper inlet flow and exit orifice size.

Initial through wall fusion is visually detectable with a steady purge, but these visual characteristics quickly disappear as the weld pool is progressed. For carbon and stainless steel during weld pool formation with 95% Argon with 5% Hydrogen shielding gas, the arc plasma will rotate in a slow circular motion. This circular movement stops and the arc stabilizes when through wall fusion occurs. During subsequent welding the arc remains motionless and gives no clue to whether or not through wall fusion is occurring.

During weld pool formation welding copper nickel or nickel copper pipe with 95% Argon and 5% Hydrogen shielding gas, the weld pool is slightly convex. When through wall fusion does occur the convex surface changes to a slightly concave surface. During subsequent welding the surface remains concave giving no hint of successful through wall fusion.

The thicker root land of square butt pipe weld joints was found to need a better method to determine through wall fusion, especially in the fixed horizontal welded pipes. Pulsed purging provided the manual welder with a positive indicator of when through wall fusion occurred throughout the weld progression.

Pulse purge is a modification of the normal purge process where a solenoid or mechanical valve is used to introduce through flow of the purge gas into the inner pipe. Rather than a constant flow and pressure in a normal straight purge, the solenoid or mechanical valve is opened and closed, creating a pressure wave that travels through the purge pipe system. Where a normal purge at pressures greater than 0.5 inches of water as measured, with a Magnehelic Gage, may result in excessive root concavity, the peak pressure of the pulsed purge wave reaching 2.5 inches of water will result in satisfactory root contours. When the weld pool has fully penetrated the pipe wall, it will move in and out in response to the changing internal pressure as the pressure wave passes through the pipe. This motion is easily visible to the welder or an observer and serves as a positive indicator of full weld bead penetration of the pipe wall. If the weld pool stops pulsing it signals the welder to stop forward progression until pulsing of the weld pool restarts, at which time forward weld progression can continue. In the horizontal fixed position the pulse purge is varied as pipe root weld bead segments are welded around the circumference. Low pulse purge pressure peaks are used on the pipe bottom and high peak pressures are used on the top of pipe welded in the horizontal fixed position.

The optimum pulse purge determined in earlier studies consist of a pulse time of 125 milliseconds with a pulse rate between 2 and 3 cycles per second. Figure 5 depicts a typical pulse purge arrangement. As this project developed the pulse purge generator was replaced by an inexpensive mechanical switch system built by the Dwight Company called the “Root Hog, Weld Root Purge Gas Device”.

Pulse Current Arc

Pulse current allows intermittent use of elevated amperages to improve weldability of pipe. It maintains acceptable weld contour while maximizing penetration in the horizontal fixed position. Successful welds were made on up to 0.216” wall thickness for carbon and stainless steel pipe. But the pipe thickness and fit-up had to be consistent for controlled timing welding. Weld pool characteristics with pulse arc will not indicate through wall fusion.

Pulse purging was found to be ineffective with pulse current. The momentary elevated amperage pulse intensified the weld pool action, masking the distinguishing characteristics of the pulse purge for determining when through wall fusion has occured.

TYPICAL PULSE PURGE ARRANGEMENT

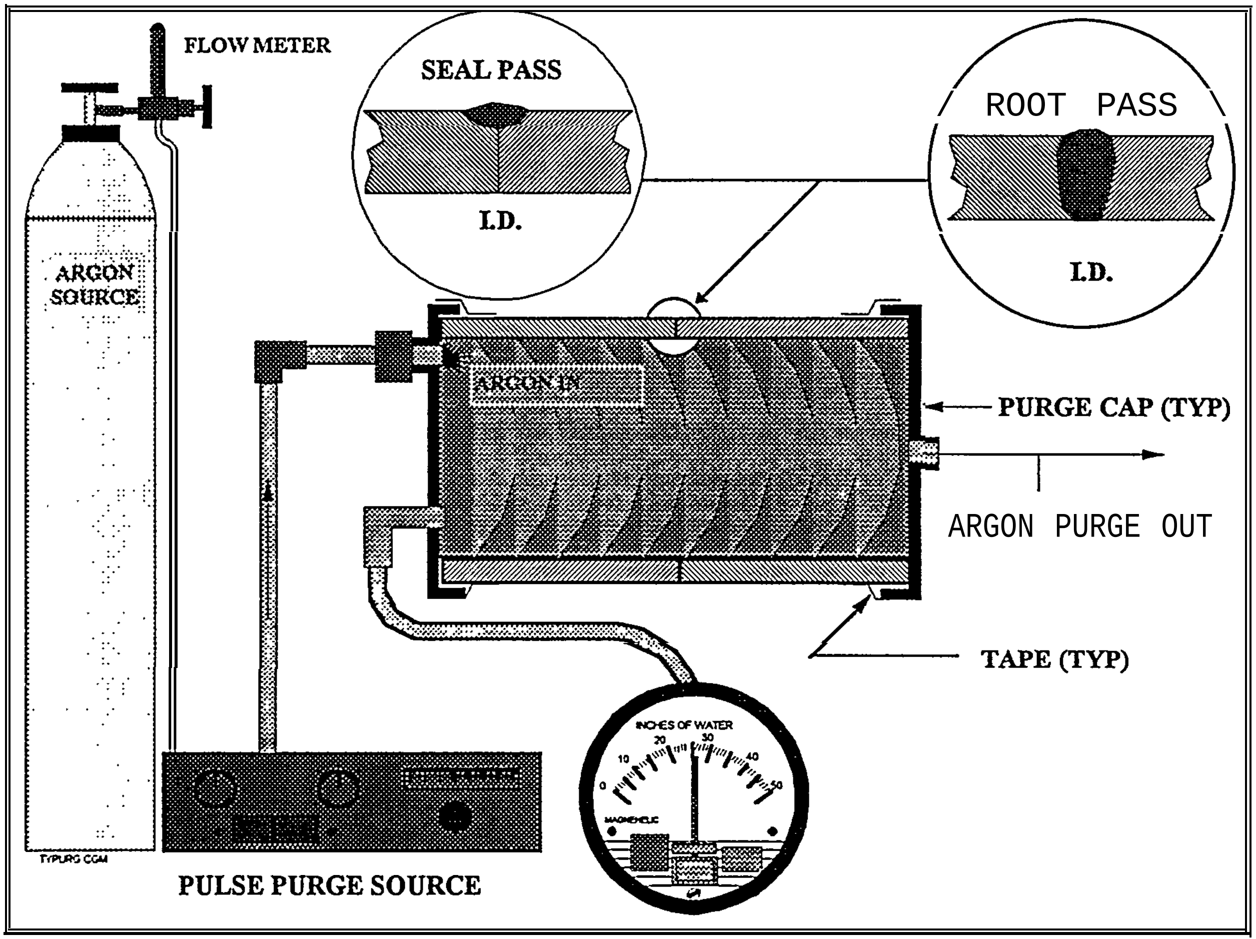


FIGURE 5

Square Butt Data

Based on the early evaluations a series of test pipe welds were made to determine the limits of square butt welding. Table I lists the "Manually Welded Square Butt Test Matrix". All pipe joints were stainless steel brushed or emery wheel cleaned of oxide and tack welded. A purged GTA seal weld pass was made circumferencially to make the joint air tight. Minor amounts of filler material were added to the seal pass when joint fit-up gap exceeded 0.030". A typical time to seal pass a 2" schedule 80 carbon steel joint was 3 minutes. Joints with large root gaps, exceeding 0.125", required larger amounts of filler material to seal. All pipe joints were GTAW in the horizontal fixed position pipe, vertical weld (5G) position using 95% Argon with 5% Hydrogen and a 90 degree blunt tungsten electrode. All welds were evaluated visually after the root pass for acceptable external weld and root contour. Large root gaps and thicker wall joints required one cover pass to achieve acceptable weld reinforcement.

TABLE I

MANUALLY WELDED SQUARE BUTT TEST MATRIX

PIPE SIZE IDENT	WALL	PIPE SIZE	STAINLESS STEEL			CARBON STEEL			CUNI		NICU	
			SA/PP (note 1)	SA/SP (note 2)	PA/SP (note 3)	SA/PP (note 1)	SA/SP (note 2)	PA/SP (note 3)	SA/PP (note 1)	SA/SP (note 2)	SA/PP (note 1)	SA/SP (note 2)
Cc	0.072"	1/2" Cls 700							45A/1.9[8]	50A/1.0[8]		
A	0.095"	1" Cls 700							50A/1.5[8]	50A/1.2[8]		
Aa	0.109"	1/2" Sch 40				50A/1.2		52A/3				
Dd	0.120"	1/2" Cls 3300							55A/1.8[8]	55A/1.0[8]		
Y	0.125"	5" Cls 200							80A/1.7	note 7		
Ff	0.130"	2" Cls 700										
C	0.133"	1" Sch 40	52A/1.2	56A/0.10	55A/3	56A/1.2	56A/.01	55A/3				
Bb	0.147"	1/2" Sch 80	60A/1.2		60A/3						90A/2.9	
E	0.154"	2" Sch 40	65A/1.4[4]	67A/0.01	67A/3			67A/3			95A/1.8	
W	0.165"	3" Cls 700							115A/1.3	note 7		
F	0.179"	1" Sch 80	65A/1.4	66A/0.01	66A/3						note 7	
Ee	0.180"	1" Cls 3300							105A/1.3	note 7		
I	0.216"	3" Sch 40	100A/1.5[5]		90A/2	120A/2.0[5]	125A/.01	120A/3				
K	0.237"	4" Sch 40										
N	0.300"	3" Sch 80	115A/1.3[6]									
V	0.438"	3" Sch 160	note 7									

NOTES FOR "MANUALLY WELDED SQUARE BUTT TEST MATRIX"

1. Data in columns referencing this note relates to welds made with a Steady Arc (SA) constant current, Pulsing Purge (PP) and 95% Argon with 5% Hydrogen shielding gas (95/5). This column documents the weld amperage used (i.e. 52A) and the peak pulse pressure measured in "inches of water" (i.e. 1.2).

2. Data in columns referencing this note relates to welds made with a Steady Arc (SA) constant current, Steady Purge Flow (SP) and 95% Argon with 5% Hydrogen shielding gas (95/5). This column documents the weld amperage used (i.e. 56A) and the constant purge pressure used in "inches of water".

3. Data in columns referencing this note relates to welds made with a Pulsing Arc (PA) pulsing current, Steady Purge Flow (SP) and 95% Argon with 5% Hydrogen shielding gas (95/5). This column documents the average weld amperage used (i.e. 55A) and the Arc Pack 350 Pulse Control Program Number (i.e. 3). Program number 3 requires a peak amperage of 69 amps (peak time of .80 seconds and background time of .53 seconds) to average 55 amps.

4. This weld was made using a 1/16" square ended tungsten.

5. These settings were used on a weld that passed X-Ray and destructive testing.

6. These settings were used on weld joints that had a 45° bevel and a 0.200" root face. One used a flat insert and the other used no insert.

7. Full penetration could not be achieved on this wall thickness.

8. This weld was made using a 1/16" 90° blunt tungsten.

9. Unless otherwise noted, all welds were made using a 3/32" 90° blunt tungsten.

10. All welding was done in the horizontal fixed position.

Material Effects

Carbon steel and stainless steel pipe joints welded equally as well. The only significant difference between the two materials was that carbon steel required about 15 percent more welding amperage. Manual welding of the square butt design, with

or without inserts, was satisfactory for up to 0.218″ wall thickness on both material types. Through wall fusion was attainable with steady arc both pulse purge and straight purge, and with pulsed arc with steady purge. Consistent and predictable results could only be obtained with the pulse purge welded joints. The use of consumable inserts in carbon steel and stainless steel joints had no visual beneficial effects on weld quality or penetration.

The modified 45 degree square butt joint used on stainless steel pipe, allowed through wall fusion on pipe wall thicknesses 0.250″ and greater. Even with this modified 45 degree square butt joint, fused wall concavity was prone to occur on wall thicknesses greater than 0.300″, which necessitated added filler wire on the cover pass.

Autogenous manual welds performed on 70% 30% and 90% 10% copper nickel produced visually acceptable weld face and root surfaces, but radiographic testing and cross sections disclosed subsurface porosity. Use of consumable MIL-67 copper nickel and MIL-60 nickel copper inserts resulted in less porosity but did not eliminate the porosity especially in the weld base metal interface. The thermal conductivity of copper nickel alloys prevented through wall fusion with the square butt joint beyond 0.150″ wall thickness.

The limited test work conducted on Monel found it to perform better than copper nickel alloys but not as well as carbon or stainless steel. The maximum depth of penetration of satisfactory welds was 0.154″.

Test Matrix Testing Results

All visually acceptable Monel, carbon steel and stainless steel welds were liquid dye penetrant tested satisfactory. Liquid penetrant tests were performed in accordance with MIL-STD-2035, Class 1. The copper nickel weld joints displayed rounded indications. Several square butt joints were submitted for radiographic evaluation to MIL-STD-2035, Class 1:

Two 304 stainless steel pipe autogenous welded, 3″ Schedule 40 (0.216″ wall thickness), tested satisfactory.

One carbon steel pipe autogenous welded, 3″ Schedule 40 (0.216″ wall thickness), test satisfactory.

Two 70/30 nickel copper pipe autogenous welded, 2″ Schedule 40 (0.154″ wall thickness), tested satisfactory.

Two 90/10 copper nickel pipe, one autogenous and one with a consumable insert, 5″ Class 200 (0.109″ wall thickness), tested unsatisfactory due to rounded porosity and pipe porosity.

The satisfactory radiographic test samples were destructive tested per MIL-STD-248C and compared to their base material specification. Results are attached (Attachments 1,2 & 3) and summarized below.

Carbon steel; Two root and two face bend tests satisfactory with no visible cracks or open defects. The two tensile tests were satisfactory with failure outside the weld area.

Stainless steel; Two root and two face bend tests satisfactory with no visible cracks or open defects. The two tensile tests were satisfactory with failure in the weld area.

70/30 Nickel copper; Two root and two face bend tests satisfactory with two samples, one face and one root, displaying small acceptable fissures. The one tensile test was satisfactory with the fracture running across the weld area from and into the opposite base material.

Autogenous Weld Chemistry

The question of thick square butt autogenous welds chemistry and effects on weld properties were investigated. As shown above destructive tensile and bend results were acceptable for plain carbon steel, stainless steel and Monel pipe weldments. The fracture of stainless steel in the weld could be expected since the remelted annealed stainless pipe weld would have a slightly lower yield strength than the wrought pipe structure. Autogenous weld chemistry was compared to the adjoining pipe base material on five pipe materials; carbon steel, stainless steel, Monel, 70% 30% copper nickel and Inconel 600. Attachments 4 through 8 give the chemical analysis of the autogenous weld, the adjacent pipe and the base material specification chemistry. No significant chemical changes were observed.

During final weld procedure qualifications one heat of stainless steel pipe and one heat of carbon steel pipe welded significantly different from all other heats tested until that time. Though these two heats did weld successfully the time for the weld to penetrate the wall was three times as long as other heats of material with the same wall thickness. The weld pool activity described earlier in the Pulse Purge section for carbon and stainless steels was absent from the start of the weld pool. The resulting arc did not maintain a narrow plasma but enlarged with a growing weld pool Size. This resulted in poorer penetration and wider finished weld beads.

In the AMI General Guidelines for Fusion Welding, Rev. July, 1991, Section “Variations in weld penetration in different heats of stainless steel:” discusses this phenomenon extracted from Burgardt and Heiple, 1986. The direction of flow in the weld puddle is believed to be fundamentally different in low sulfur heats, 0.001-0.007% (or low oxygen to a lesser extent) than when

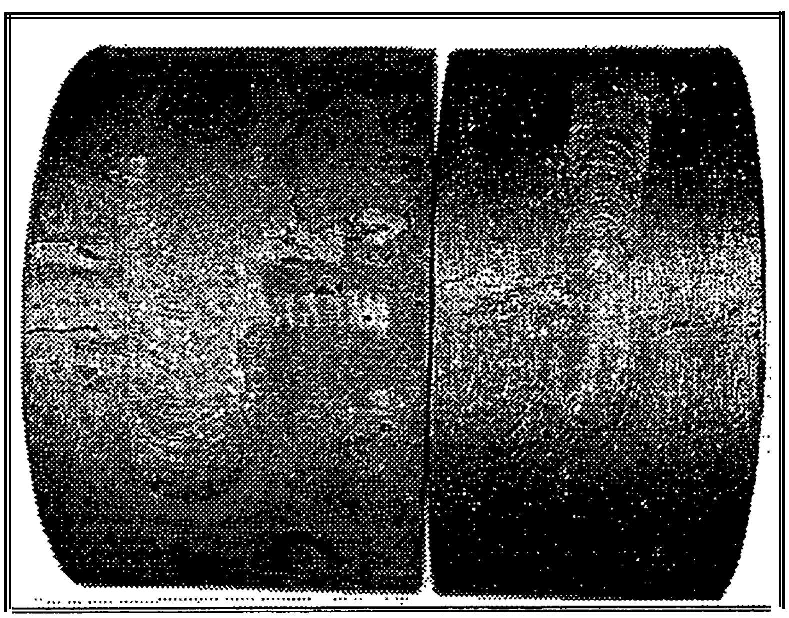
some sulfur is present. The direction of fluid flow is outwards and thus the puddle is wide and shallow. In normal sulfur content heats, 0.008-0.030% the fluid flow is inward and down resulting in deeper weld bead penetrations.

Chemistries for the poor acting heats were compared to normal weldable pipe heats that penetrated easily. The one poor welding heat of stainless steel pipe had the same typical chemistry as the normal welding pipe heats~ except it had only 0.001% sulfur. The one pipe heat of carbon steel that welded poorly tested <0.003% sulfur. One marginal weldable heat of carbon steel tested 0.004% sulfur. All normal welding pipe heats of carbon and stainless steel had at least 0.007% sulfur. Attachments 9 through 14 are the full chemical analyses for the poor and marginal weldable pipe heats and a typical chemistries of good weldable pipe heats for carbon and stainless steel.

To demonstrate this sulfur effect on welding, a single weld bead on pipe wall was run on a low sulfur(<0.003%) content carbon steel pipe and a normal sulfur (0.023%) content pipe. The heat inputs were the same. All parameters were consistent. Amperage, voltage hold start time and travel speed were identical. Photograph 2 shows the surface weld bead difference between the low sulfur carbon steel pipe and the normal sulfur carbon steel pipe. Photograph 3 is the low sulfur content pipe weld profile and Photograph 4 is the normal sulfur content pipe. The low sulfur content carbon steel pipe results in a wide non-penetrating weld bead and the normal sulfur carbon steel pipe results in a narrow penetrating weld bead under the same conditions.

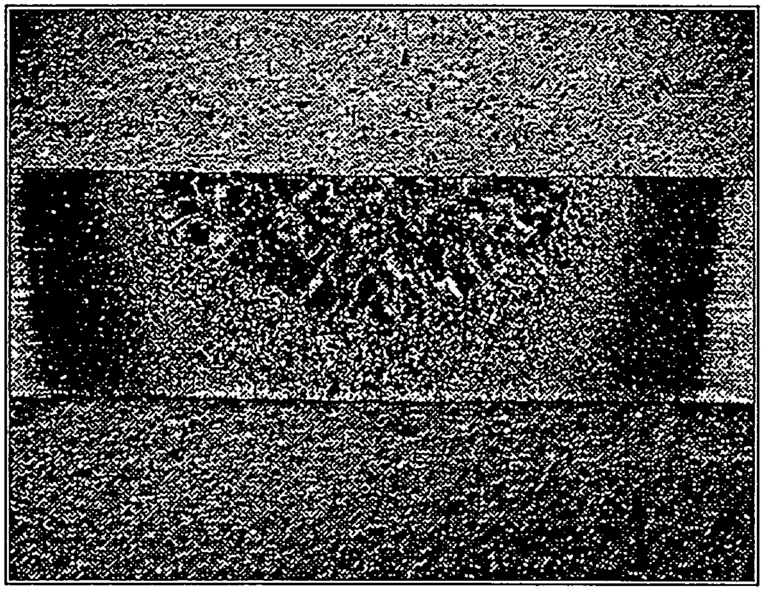
WELD BEAD SURFACE

LOW SULFUR (<0.003%) NORMAL SULFUR (0.023%)



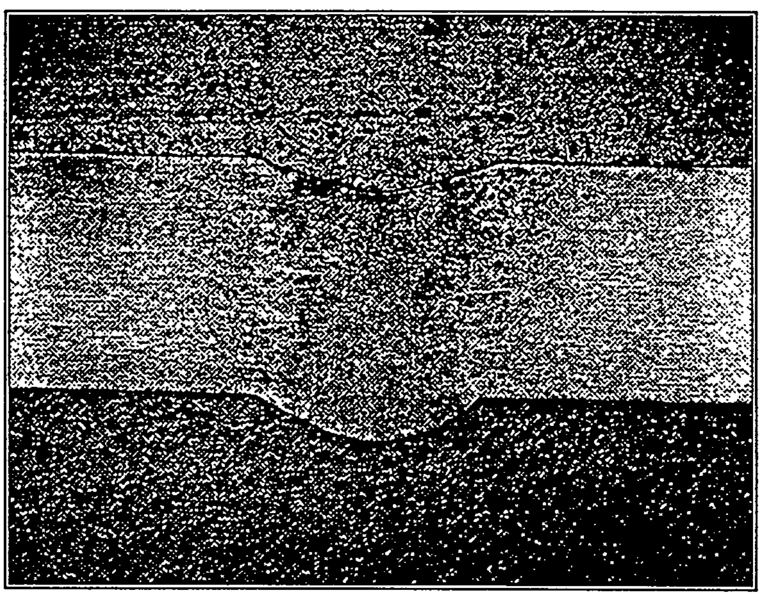
Photograph 2

LOW SULFUR WELD BEAD PROFILE



Photograph 3

NORMAL SULFUR WELD BEAD PROFILE



Photograph 4

The effect of sulfur content in the base pipe material appears to be a major factor in time to penetrate the wall thickness in welding and the resulting weld bead width. Only extremely low sulfur contents, <0.004% sulfur, affect weld quality for the manual square butt pulse purge techniques qualified because of their flexibility. As discussed later in the report, this sulfur content effect on penetration timing prevents consistent weld techniques for automatic thick wall square butt welding.

Manual Weld Procedure Qualifications

Three sets of manual pipe weld procedure qualifications were welded and tested to MIL-STD-248C (also meets MIL-STD-248E and S9074-AQ-GIB-O10/248 Rev. O requirements) . Carbon steel, stainless steel and Monel pipe materials were square butt welded using pulse purge. All pipe joints were saw cut, stainless steel brushed or emery wheel cleaned of oxide and tack welded. A purged GTA seal weld pass was made circumferencially to make the joint air tight. Filler material was added to the seal pass when the joint fit-up gap exceeded 0.030". The time to make this seal pass was less than 3 minutes. All pipe joints were GTAW in the horizontal fixed position pipe, vertical weld (5G) position using 95% Argon with 5% Hydrogen torch gas and a 90 degree included angle blunt tungsten electrode for the root and seal pass. A four to one taper tungsten electrode was used with filler material on the cover pass. For the seal and cover pass a straight inner pipe Argon purge was used. For the root pass the pulse purge was utilized as described earlier in the report. Four 2" Schedule 80 pipe assemblies for carbon steel and stainless steel were welded and tested for the procedure qualifications. Three 2" Schedule 40 Monel pipes were welded for procedure qualifications.

Al 1 test assemblies were visually inspected to PSNS Industrial Process Instruction (IPI) 0074-905 Rev. A for compliance with pipe classes P-1 and P-2 for MIL-STD-278 and MIL-sTD-248c requirements. All were satisfactory, meeting the weld reinforcement, convexity and concavity requirements for both inner and outer surfaces. The carbon steel pipe assemblies were magnetic particle inspected while the stainless steel and Monel pipe assemblies were liquid penetrant inspected per MIL-STD-2035, Class 1. All assemblies were satisfactory. Finally all pipe weld assemblies were radiographed per MIL-STD-2035, Class 1. Al 1 pipe weld assemblies radiographed satisfactory.

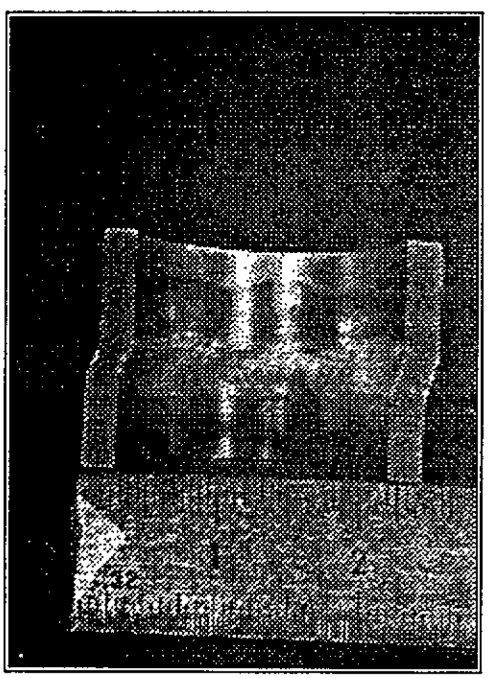
As per MIL-sTD-248, two of the 2" pipe weld assemblies from each material type were tensile tested as full pipe weld assemblies. In addition a third assembly was sectioned to provide two face bends, two root bends and two macro samples. Fourth assemblies were sectioned for samples. All tensile, bend tests and macros were satisfactory and meet the requirements of MIL-STD-248C and MIL-STD-278. For the stainless steel, two additional root bend samples were tested satisfactory per MIL-sTD-248C requirements for corrosion sensitivity per Practice E of ASTM A262. Attachments 15, 16 and 17 report the destructive testing results summarized above.

For carbon steel and stainless steel a matrix of additional pipe sizes and wall thicknesses were prepared as the 2" diameter pipe assemblies and welded to determine the full range of welding amperages for various wall thicknesses. Root openings were varied from 0.0 up to 0.125". Filler metal was added to the seal pass with root gaps exceeding 0.030". All test assemblies were visually inspected to PSNS Industrial Process Instruction (IPI)

0074-905 Rev. A for compliance with pipe classes P–1 and P-2 for MIL-STD-278 and MIL-STD-248C requirements. All were satisfactory, meeting the weld reinforcement, convexity and concavity requirements for both inner and outer surfaces. The carbon steel pipe assemblies were magnetic particle inspected while the stainless steel pipe assemblies were liquid penetrant inspected per MIL–STD–2035, Class 1. All assemblies were satisfactory. Finally, all pipe weld assemblies were radiographed per MIL-STD-2035, Class 1- All pipe weld assemblies radiographed satisfactory. Pipe assemblies with mismatch of pipe wall fit-up exceeding 25% of the wall thickness were also welded. These mismatch square butt weld assemblies were visually acceptable and cross sectioned to confirm contour acceptability. Photograph 5 shows the profile and cross section of a typical root pass on a 40% mismatch square butt joint.

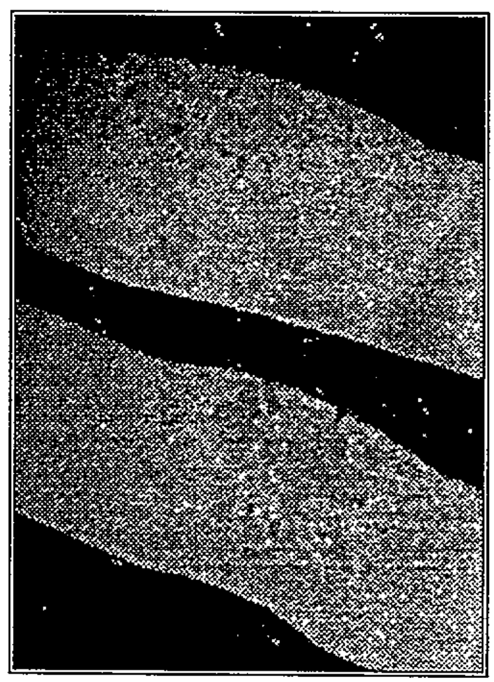
Attachments 18, 19 and 20 summarize the square butt, pulse purge pipe weld procedures submitted to NAVSEA for approval for carbon steel, stainless steel and Monel pipe materials. Photographs 6, 7 and 8 are etched cross sections of the qualification pipes showing the root pass (and its consumption of the seal pass) and the cover pass.

40% MISMATCH ASSEMSLY



Photograph 5

CARBON STEEL

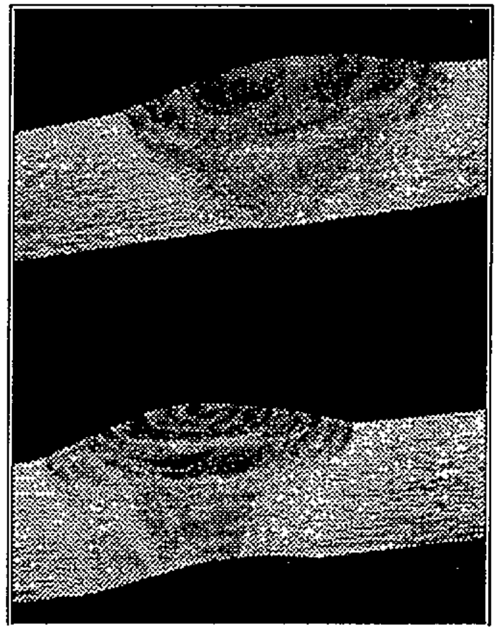


Photograph 6

STAINLESS STEEL

Photograph 7

MONEL



Photograph 8

Automatic:

A limited number of automatic square butt weld assemblies were made. All square butt pipes were welded with an Arc Machine Inc. Orbital welder. The AMI welder maintains the tungsten electrode arc length through utilization of an Automatic Voltage Control(AVC) function. When the pulse purge was used with the AMI welder the pulsating weld pool would cause instant termination of the arc when the tungsten electrode contacted the weld pool. The AVC sustaining the arc length could not react quickly enough to the weld pool movement. For this reason all automated pipe welds utilized a steady purge with a pulsed current. Initial evaluations, run on the AMI Model 15 head, found as in manual welding that 95% Argon with 5% Hydrogen shielding provided deeper penetration than 100% Argon. Both a 4 to 1 taper design and a blunted 90 degree tungsten electrode were evaluated.

All first trial test welds used the 95% Argon 5% Hydrogen shield gas and the blunt 90 degree tungsten electrode. Table II "AMI Square Butt Data Chart list the joint types and settings that produced visually satisfactory pipe welds. All were single pass welds with either with an insert or no insert square butt joint design (see Figure 6) welded in the horizontal pipe position (5G). Root gap fit-up was tighter than manual and pipe wall mismatch were minimized for consistent weld penetration.

TABLE II

AMI SQUARE BUTT DATA CHART

	0.150" WALL			0.200" WALL			0.250" WALL			0.300" WALL		
	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3
STAINLESS STEEL				135/45 5.3 - 7	140/45 6.5 - 7.7	130/45 6.6 - 7.5	160/45 5 - 6	152/45 4 - 6.5	152/45 4 - 6.5	180/50 2.8 - 3.2		
CARBON STEEL				155/45 5.3 - 6	155/45 5.3 - 6	155/45 5.3 - 6						
COPPER NICKEL												
NICKEL COPPER												

NOTES :

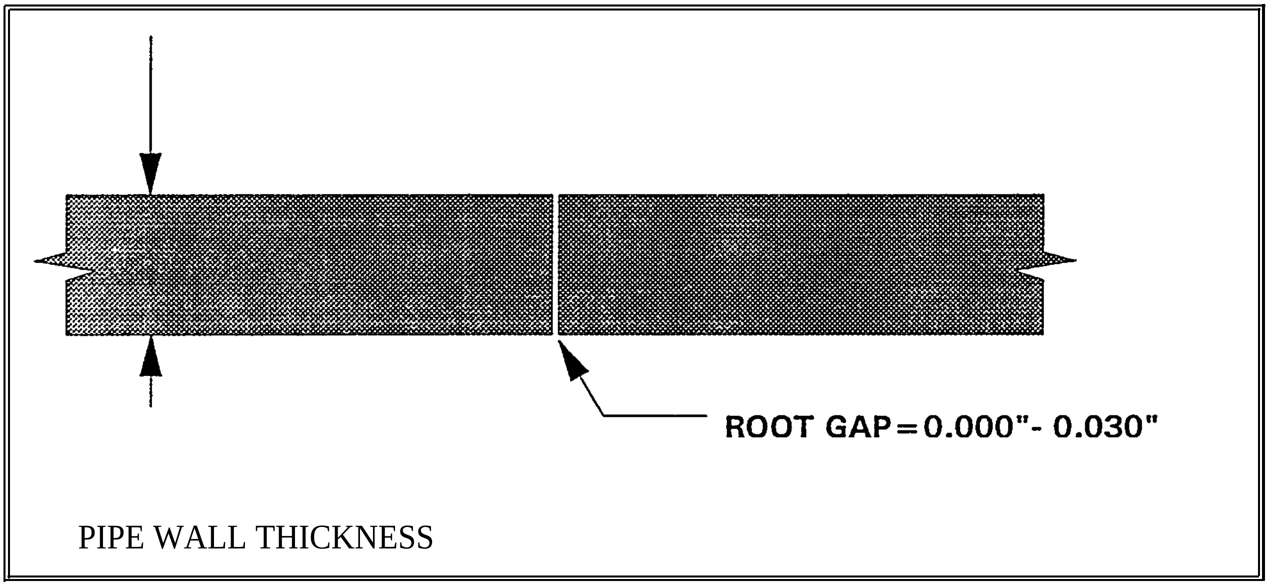
1. Each space on the chart represents a test weld.

2. All Jt 1 & Jt 2 welds will be made on a saw cut square butt weld end prep, see Figure 9. Two consecutive welds will be made on this end prep to confirm repeatability of weld results.

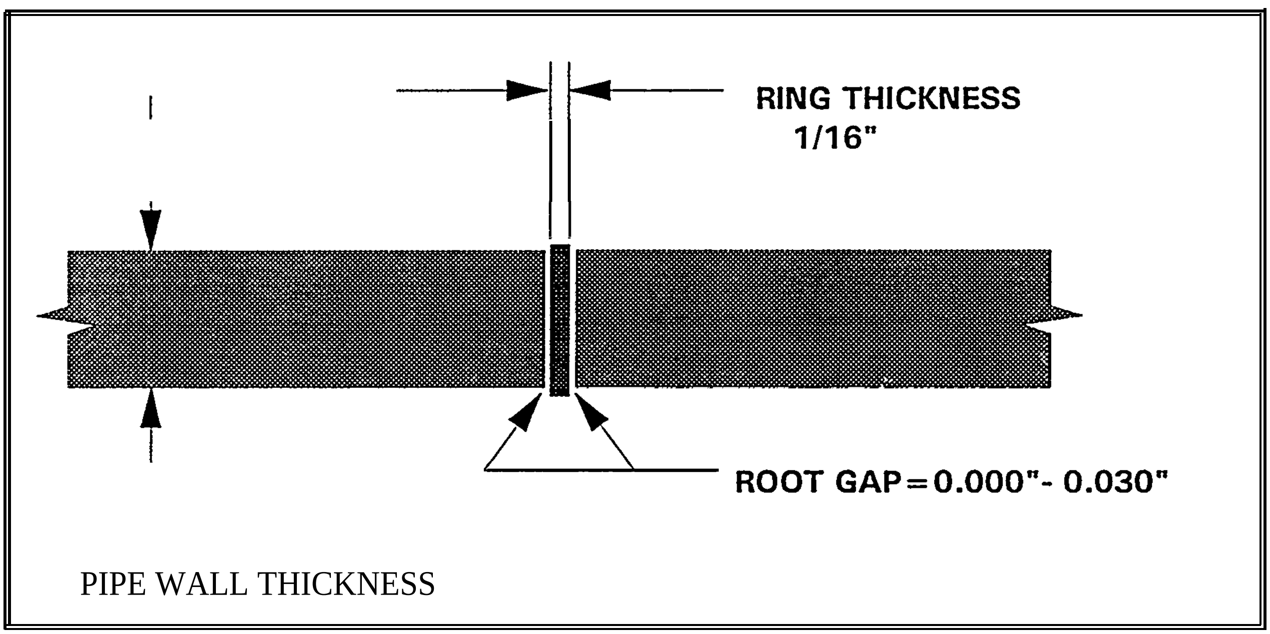
3. Jt 3 welds will be made on a saw cut square butt weld end prep with a 1/16" thick flat consumable insert with a depth equal to or slightly greater than the wall thickness of the test pipe, see Figure 9.
4. Data entries in each space will document welding results. Acceptable tests will list the weld amperage (primary amps and background amps [i.e. 155/45]) and the travel speeds in inches per minute (slowest to the fastest [i.e. 5.3 - 6]) that were used.

5. All welding will be done in the horizontal fixed position, unless otherwise noted.

AUTOMATIC SQUARE BUTT JOINT DESIGN



JOINTS #1 AND # 2



JOINTS #3

FIGURE 6

A pulsing arc operating in the “step mode” was utilized. In the step mode, the torch moves ahead while on the background current and remains stationary while on the primary current setting. Typical schedules for carbon and stainless steel pipe welds are attached (see Attachments 21 and 22). Amperage settings would remain constant around the circumference of the pipe weld and the travel speed varied during weld progression to compensate for weld bead position and heat buildup. The internal root contour of these weld joints is slightly convex on the top (less than 1/16”) and slightly concave on the bottom (less than 1/16”). The working range of parameters (primary amperage, background amperage and travel speed) narrows to produce acceptable internal root contour as the wall thickness increased.

The first trial set produced acceptable square butt weld joints but was obtained on pipes with consistent wall thickness and fit-up tolerance. As in square butt manual welding, a weld procedure qualification test series was attempted. Two inch schedule 40 stainless steel pipe with a nominal wall thickness of 0.154” was selected as the first and most likely qualification candidate.

The heat chemistry of the schedule 40 stainless steel pipe was extremely low sulfur (0.001%). As discussed in the manual pipe weld chemistry effects, this low sulfur chemistry resulted in weld beads that were wide and shallow. Through penetration time was inconsistent and no single weld schedule would give acceptable weld contour and penetration.

Additional heats of stainless steel pipe were successfully welded without shallow penetration problems but the schedules developed varied with each heat of material. As discussed in the background section, Wellons controlled seam welded pipe wall thickness to plus or minus 0.003” and square butt joint fit-up from 0.0 to 0.010” gap. With these tight tolerances the automated schedule was divided into seven weld power and speed control segments that vary only 3% in magnitude. Puget Sound Naval Shipyard (PSNSY) uses seamless pipe with a larger variance in wall thickness. Pipe joint fit-up tolerances at PSNSY are generally allowed up to 0.030”. It was determined that for a given heat chemistry, consistent wall thickness and a machined fit-up, less than 0.015” gap, a automated weld schedule for the AMI could be made. But a general schedule for all heat lots with varying chemistry, varying wall thickness and non-machined tolerances could not be developed for production welding of thick square butt joints.

Discussion:

A technique for manually welding square butt thick pipe sections up to 0.250” was developed. The use of pulse purge was necessary in order to ensure complete penetration with no excessive concavity or convexity. The pulse intensity was varied for horizontal fixed pipe joints around the perimeter. For

vertical fixed and horizontal roll positions the pulse need not be varied in intensity.

The economic advantages of using pulse purge square butt are many. First the joint preparation time of saw cut versus cut and angle machine or grind is an order of magnitude in time. The cost of the pulse purge unit (<$200) is much cheaper than the tools or machinery for end preparation on conventional joints. No insert costs and the reduction of filler material needed also reduces costs. The total weld time for a typical 2 schedule 80 joint with seal, root and cover pass is one half hour including cool down time between segments. Fit-up time could be reduced as well due to the looser fit-up tolerances of the square butt joint than an insert joint. A conventional plain carbon v-groove insert joint fit-up and weld is allotted 4.2 hours by PSNSY standards. A reduction of one to two hours would be expected if the square butt joint design were substituted. With reduced weld times consumption of purge gas would also be reduced.

The time to retrain pipe welders to use pulse purge was found to be less then one day. After welding several practice joints, the visual observation of the pool pulsing and slower root pass was learned. The time to train new pipe welders should be reduced over conventional pipe joints, since the pulse purge technique relies on visual observation only and not time counting or experience for various materials, thicknesses and joint configurations.

Conclusions:

Acceptable manual thick section square butt pipe welds can be made in carbon steel, stainless steel and Monel base materials. Welded copper nickel pipe base materials produced unacceptable defects in the fusion line and could not pass nondestructive testing (i.e. porosity) . Carbon steel, stainless steel and Monel could be square butt welded up to 0.154″ with or ‘without an insert with 100% Argon shield gas and an inner pipe purge. The use of a inner pipe pulse 100% Argon purge and 95% Argon 5% Hydrogen shield gas allowed consistent acceptable pipe welding for carbon and stainless steel up to 0.250″ pipe wall thicknesses. Thicker sections could be welded with a modified 45 degree bevel square butt joint. Square butt joints with weld fit-up gaps up to 0.250″ and wall mismatch up to 25% were successfully welded with the pulse purge technique. The effect of base material sulfur content was found on the time to penetration the pipe wall; resulting in increased bead width and poor weld root contour.

Manual squrarebutpulseslse purge weld procedures for carbon steel and stainless steel pipe up to 0.250″, and Monel pipe up to 0.154″ were qualified per MIL-STD-248 and MIL-STD-278 latest revisions. Automatic procedures were not consistent due to varying wall thickness and sulfur chemistry effects on time for through wall penetration.

CARBON STEEL TEST DESTRUCTIVE RESULTS

JAN. *28 1994*

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report: 94 PSO1805

Job Order:	**8134590001001**	Date Received:.	940124
submit Shop-:	Code 138.2	Specification:	S1 PER ASTM A106
Submit Ship:	Code 138	Composition:	B
Test:	Bend	Laboratory Branch:	134.6
N~ Samples:	6	Traceability:	WELD JOINT #IAH4
Description:	TENSION SPECIMENS ROOT/FACE BENDS PIPE		

SIX SAMPLES, (2ea.face bends,2ea.root bends,2ea.tension) WERE TESTED"

AS REQUESTED BY C/138. RESULTS ARE AS FOLLWS:

TENSILE SPECIMENS: AREA	ACTUAL	REQUIRED
(.1034)	#l=77,000psi	60,000psi.min.
(.0994)	#2=76,000psi	

BOTH FAILURES OCCURED OUTSIDE OF THE WELD.

BEND SPECIMENS: TWO Rti AND TWO FACE BENDS WERE MADE WITH A BEND RADIUS OF 3/8"(3/4" MANDREL).
SPECIMENS HAD A THICKNESS OF 13/64".
ALL FOUR SPECIMENS CONTAINED NO VISIBLE CRACKS OR OPEN DEFECTS.

Remarks: ITEMS WERE TESTED PER MIL-STD-248C

Complete: Sample(s) meet specification

Nancy Nuxx 1/28/94	[illegible] 1/28/94
Operator (C/134.6) Date	Reviewer (C/134.6) Date

Distribution: Code 138.2, LANGHELM 6-8808

"The person designated to sign for an action verifies, -based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements -"

STAINLESS STEEL DESTRUCTIVE TEST RESULTS

JAN. 26 1994

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report: 94 PS01806

Job Order: 8134590001001
Submit Shop: Code 138.2
Submit Ship: Code 138
Test: Bend
Num Samples: 6
Description: TENSION SPECIMENS ROOT/FACE BENDS PIPE

Date Received: 940124
Specification: SA PER MILT23226
Composition:
Laboratory Branch: 134.6'
Traceability: WELD JoINT #lBGl

SIX SAMPLES,(2ea.face bends,2ea-root bends,zea. tension) *WERE* TESTED

AS REQUESTED BY. C/138. RESULTS ARE AS FOLLOWS:

TENSILE SPECIMENS: AREA		ACTUAL	REQUIRED
(.1134)	#1=	85,000psi	75,000 psi min.
(.1151)	#2=	85,000psi	

BOTH FAILURES OCCURED IN THE WELD.

BEND SPECIMENS: TWO ROOT AND TWO FACE BENDS WERE MADE WITH A BEND RADIUS OF 3/8"'(3/4" MANDREL).
SPECIMENS HAD A THICKNESS OF 13/641'.
ALL FOUR SPECIMENS CONTAINED NO VISIBLE CRACKS OR OPEN DEFECTS.

Remarks: ITEMS WERE TESTED PER MIL-STD-.248C

Complete: Sample(s) meet specifications

Ilirmnli Watl	1/28/94	[signature]	1/20/94
Operator (C/134.6)	Date	Reviewer (C/134.6)	Date

Distribution: Code 138-2, LANGHELM 6-8808

"The person designated to sign fOr an action Verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements."

70/30 NiCo

APR. 26 1995

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 95PS05683

Job order	8134590001001	Date received	950419
Submit shop	Code 138.2	Specification	MILT23520
Submit ship	Code 138	Composition	MISC
Test	Tensile, Lab Proc. 005	Branch	134.6
Num samples	1	Trace number	WELD JOINT#EDH-4
Description	AUTOGENOUS PIPE WELD SAMPLE		

THE PIPE WELD SAMPLE WAS TENSILE TESTED AS REQUESTED BY C/138,THE

RESULTS ARE AS FOLLOWS:

CROSS-SECTIONAL AREA	.ACTUAL U.T.S	REQUIRED U.T.S. FOR THE PIPE
1.116	81,500 psi	70,000 psi min.

THE FRACTURE OCCURED IN THE UPPER PIPE RUNNING THROUGH THE WELD INTO THE LOWER PIPE.

Remarks:

Complete: For information only

Nancy Mery 4/26/95

Reviewer (C/134.6)

Distribution: Code 138.2, LANGHELM 6-8808

"The person designated to sign for an action verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements."

LABORATORY DIVISION REPORT, CODE 134.6 (METALLURGY)
13ND PSNS 4730/266 (10-73)

RECORD NO. 95 PS 06446

TO CODE/SHOP	NAME	JOB ORDER
138.2	Langhelm	81345-90001-001

SUBJECT: Weld Joint No. EDG-2

SUBJECT MATERIAL: NiCu pipe - MIL-T-23520

DRAWING NO.	PIECE NO.	ACCEPTANCE SPECIFICATION	PROCEDURE

TESTS
- [ ] CHEMICAL
- [ ] SPOT TEST
- [ ] HARDNESS
- [ ] TENSILE
- [x] BEND
- [ ] MACRO
- [ ] MICRO
- [ ] SPRING LOAD
- [ ] PROOF LOAD
- [ ] BREAKING LOAD
- [ ] OTHER

DESCRIPTION AND/OR SKETCH

Two face bend and two root bend specimens from weld joint no. EDG-2 have been subjected to a guided bend test in accordance with AWS B4.0

Test Parameters: Specimen thickness = 5/32 inch
Bend radius = 3/8 inch

TEST RESULTS AND REMARKS

- [ ] ACCEPT
- [ ] REJECT
- [x] INFORMATION

One face bend and one root bend specimen are free of cracks and other open defects.

One face bend specimen contains a single fissure 0.050" long on the convex surface of the specimen.

One root bend specimen contains four fissures, 0.040", 0.040", 0.030", and 0.020" long on the convex surface of the specimen.

Remarks: All defects observed on the convex surfaces of the guided bend specimens are less than 1/8" long.

The guided bend specimens meet the acceptance criteria of MIL-STD-248C, para. 4.5.2.3.1.

OPERATOR (SIGNATURE)	DATE	REVIEWER (SIGNATURE)	DATE
J Becker	5-5-95	[signature]	5/5/95

DISTRIBUTION: 138.2

CARBON STEEL WELD **CHEMICAL ANALYSIS**

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PS07491

Sample(s) submitted by C/138 Weld Engr
Sample logged in 950524

End user Code 138
Job order 813459ooo1oo1
Sample identification PIPE WELD
Lab procedure 149

Element	Sample number, ID 001 BASE	002 WELD					ASTM A106-94 A Specification Requirements, % Min	Max
Aluminum								
Carbon	.13	.11						.25
Chromium	.01	.01						.40
Copper	.01	.01						.40
Manganese	.43	.42					.27	.93
Molybdenum	<.01	<.01						.15
Nickel	.01	.01						.40
Niobium								
Phosphorus	.007	.006						.035
Silicon	.13	.13					.10	
Sulfur	.020	.014						.035
Titanium								
Vanadium	<.01	<.01						.08

Remarks: Complete: For information only

Note: For each reduction of .01% below the specified carbon maximum an increase of 0.06% Mn above the specified maximum will be permitted up to a maximum of 1.35%.

MAY 26 1995

Code 134.1 analyst, Merkt
Wayne Merkt 0845
150783 5/26/95

Code 134.1 reviewer
G. Ruedelbusch
5/26/95

Distribution: C/138 Weld Engr
LANGHELM

Attachment 4
Page 1 of 1

STAINLESS STEEL WELD CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PS07581

Sample(s) submitted by C/138 Weld Engr
Sample logged in 950525

End user
job order 8134590001001
Sample identification PIPE WELD

Element	001 BASE	002 WELD				MILT23226A 304 Specification Requirements, percent Min	Max
Boron	.002	.002					.005
Carbon	.05	.05					.08
Chromium	19.69	19.72				18.00	20.00
Cobalt	.10	.10					.10
Copper	.23	.22					
Manganese	1.46	1.45					2.00
Molybdenum	.33	.33					
Nickel	10.28	10.51				8.00	12.00
Niobium							
Phosphorus	.028	.029					.030
Silicon	.54	.53					.75
Sulfur	.009	.011					.030
Titanium							
Vanadium							

Remarks: Complete: For information only Lab procedure 300

MAY 26 1995
Code 134.1 analyst, J. Haynes 154258 Code 134.1 Reviewer

Distribution: C/138 weld Engr
LANGHELM

7604

Attachment 5
Page 1 of 1

70/30 NICKEL COPPER WELD CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PS07583

Sample(s) submitted by C/138 Weld Engr
Sample logged in 950525

End user
Job order 8134590001001
Sample identification PIPE WELD
Lab procedure 305

Element	Sample number, ID					MILT23520A Specification Requirements, percent	
	001 BASE	002 WELD				Min	Max
Aluminum	<.1	<.1					.50
Carbon	.1	.1					.20
Chromium	.3	.3					
Cobalt	.09	.10					.20
Copper	33.	33.				Remainder	
Iron	1.00	1.04					2.50
Lead	<.006	<.006					.006
Manganese	1.09	1.16					1.25
Molybdenum							
Nickel	64.	64.				63.	70.
Phosphorus	.01	.01					.02
Silicon	.21	.22					.50
Sulfur	.001	.006					.015
Tin	<.006	<.006					.006
Titanium							
Zinc	*	*					

Remarks: Complete: For information only
* Unable to analize for Zinc in this alloy.

Code 134.1 analyst, J. Haynes 154258 JUNE 7 1995
Code 134.1 Reviewer BSmith 152487 6/8/95

J. Haynes

Distribution: C/138 Weld Engr
LANGHELM

Attachment 6

70/30 COPPER NICKEL WELD CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PS07582

Sample(s) submitted by C/138 Weld Engr
Samplee legged in 950525

End user
Job order 8I34590001001
Sample identification PIPE UELO

Element	Sample number 001 BASE	002 WELD			MILT16420K 70-30 Specification Requirements, percent Min	Max
Aluminum						
Carbon	<.01	<.01				.05
Cobalt						
Copper	67.7	67.7			65.0	
Iron	.57	.58			.40	1.0
Lead	<.01	<.01				.05
Magnesim						
Manganese	.7	.7				1.0
Nickel	30.8	30.7			29.0	33.0
Niobium						
Phosphorus	.01	.01				.05
Silicon						
Sulfur	.01	.01				.05
Tin						
Zinc	.18	.13				.50
Cu + elements with speciific limits	100.0	99.9			99.5	

Remarks: Complete: For information only

Lab procedure 304

Code 134.1 analyst, Herkt

Distribution: C/138 Weld Engr
LANGHELM

Wayne Herkt 1400
150783 5/26/95

[illegible]

INCONEL 600 WELD CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report 95pso7584

Sample(s) submitted by C/138 Weld Engr
Sample logged in 950525

End user
Job order 8134590001001
Sample identification PIPE WELD

Element	Sample number, ID					MILT23227 Modified Specification Requirements, percent	
	001 BASE	002 WELD				Min	Max
Aluminum	.22	.22					
Boron							
Carbon	.019	.013					.15
Chromium	15.77	16.22				14.00	17.00
Cobalt	.05	.05					
Copper	.25	.26					.50
Iron	8.53	8.59				6.00	10.00
Magnesium							
Manganese	.52	.53					1.00
Molybdenum							
Nickel+ Cobalt							
Niobiun							
Phosphorus							
Silicon							
Sulfur							
Tantaiun							
Titaniun							

Remarks: Complete: For information only Lab procedure 150

June 7 1995
Code 134.1 analyst, J. Hayms 154258

Code 134.1 Reviewer
BSmith 152487
6/8/95

Distribution: C/138 Weld Engr
LAHGHELH

Attachment 8
Page 1 of 1

POOR WELDING STAINLESS STEEL CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PSI5629

Sample(s) submitted by C/138 Weld Engr
Sample logged in 951212
Trace number N002514346K428-N002515097K825

End user C138
Job order 8134590001001
Sample identification WELD QUAL

Element	Sample number, ID: PPSS-6					MIL-P-1144 304 Specification Requirements, percent Min	Max
Aluminum							
Carbon	.04						.08
Chromium	18.0					18.0	20.0
Cobalt							
Copper							
Manganese	1.90						2.00
Molybdenum							
Nickel	10.13					8.00	11.00
Niobium							
Phosphorus	.027						.040
Silicon	.47						.75
Sulfur	.001						.030
Titanium							
Vanadium							

Remarks: Complete: Sample(s) meet specifications Lab procedure 300,134

DEC. 15 1995
Code 134.1 analyst, D. Vincent 155054 Code 134.1 Reviewer
D. Vincent 415248
12/15/95

Distribution: C/138 Weld Engr
SCHECTENS

Attachment 9
Page 1 of 1

GOOD WELDING STAINLESS STEEL CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 95PS15057

Sample(s) submitted by C/138 Weld Engr
Sample logged in 951129
Trace number 42437001

End user Code 138
Job order 8134590001001
Sample identification WELD QUAL 2" PIPE

Element	Sample number, ID					MILP24691/3 TP304 Specification Requirements, percent	
	PPSS-1					Min	Max
Aluminum							
Carbon	.05						.08
Chromium	18.1					18.0	20.0
Cobalt							
Copper							
Manganese	1.77						2.00
Molybdenum							
Nickel	10.2					8.00	11.0
Niobium							
Phosphorus	.028						.040
Silicon	.52						.75
Sulfur	.007						.030
Titanium							
Vanadium							

Remarks: Complete: Sample(s) meet specifications Lab procedure 300,134

DEC. 6 1995

Code 134.1 analyst, D. Vincent 155054 Code 134.1 Reviewer

D. Vincent Smith 152457 12/7/95

Distribution: C/138 Weld Engr
SCHELTENS

Attachment 10
Page 1 of 1

MORE GOOD WELDING STAINLESS STEEL CHEMICAL ANALYSES

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 96PsO0969

Sample(s) submitted by C/138 Weld Engr
Sample logged in 960122
Trace number P-1,2,3

End user Code 138
Job order 8134590001001
Sample identification PIPES,CRES

Element	Sample number, ID 001 P-1	002 P-2	003 P-3			ASTM A312-94 TP304 Specification Requirements, percent Min	Max
Aluminum							
Carbon	.04	.04	.02				.08
Chromium	19.4	19.0	18.5			18.0	20.0
Cobalt							
Copper							
Manganese	1.72	1.53	1.85				2.00
Molybdenum	.12	.25	.04				
Nickel	10.3	10.0	10.4			8.00	11.0
Niobium							
Phosphorus	.033	.029	.014				.040
Silicon	.46	.55	.28				.75
Sulfur	.024	.011	.006				.030
Titanium							
Vanadium							

Remarks: Complete: Sample(s) meet specifications Lab procedure 300

MIL-P-1144 refers to ASTM A312 for chemical requirements.

JAN. 30 1996
Code 134.1 analyst, D. Vincent 155054 Code 134.1 Reviewer

D. Vincent [signature] 152487 1/31/96

Distribution: C/138 Weld Engr
SCHELTENS

POOR WELDING CARBON STEEL CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 965PS00967

Sample(s) submitted by C/138 Weld Engr
Sample logged in 960122
Trace number NA

End user Code 138
Job order 8134590001001
Sample identification PIPE,SCA 80,2"
Lab procedure 149

Element	Sample number, ID 001						ASTM A106-94 A Specification Requirements, % Min	Max
Aluminum								
Carbon	.14							.25
Chromium	.05							.40
Copper	.07							.40
Manganese	.69						.27	.93
Molybdenum	.02							.15
Nickel	.06							.40
Niobium								
Phosphorus	.004							.035
Silicon	.11						.10	
Sulfur	<.003							.035
Titanium								
Vanadium	<.01							.08

Remarks: Complete: Sample(s) meet specifications

MIL-P-24691/1 refers to ASTM A106 for chemical requirements.

JAN. 23 1996
Code 134.1 analyst, D. Vincent 155054
D. Vincent

Code 134.1 reviewer
Smith 152487
1/23/96

Distribution: C/138 Weld Engr
SCHELTENS

MARGINAL WELDING CARBON STEEL CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 96PS00968

Sample(s) submitted by C/138 Weld Engr
Sample logged in 960122

End user Code 138
Job order 8134590001001
Sample identification PIPE,SCA 80,2"
Lab procedure 149

Element	Sample number, ID 001						ASTM A106-94 B Specification Requirements, % Min	Max
Aluminum								
Carbon	.16							.30
Chromium	.03							.40
Copper	<.02							.40
Manganese	.98						.29	1.06
Molybdenum	.02							.15
Nickel	.04							.40
Niobium								
Phosphorus	.006							.035
Silicon	.24						.10	
Sulfur	.004							.035
Titanium								
Vanadium	<.01							.08

Remarks: Complete: Sample(s) meet specifications

MIL-P-24691/1 refers to ASTM A106 for chemical requirements.

JAN. 23 1996

Code 134.1 analyst, D. Vincent 155054

D. Vincent

Code 134.1 reviewer

B Smith 152487
1/23/96

Distribution: C/138 Weld Engr
SCHECTENS

ADDITIONAL GOOD AND MARGINAL WELDING CARBON STEEL CHEMICAL ANALYSIS

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
LABORATORY DIVISION

Report number 96PS01263

Sample(s) submitted by C/138 Weld Engr
Sample logged in 960126
Trace number PPCS 5,6,7,8,9

End user Code 138
Job order 8134590001001
Sample identification WELD QUAL.,STEEL
Lab procedure 149

Element	001 PPCS-5	002 PPCS-6	003 PPCS-7	004 PPCS-8	005 PPCS-9		ASTM A106-94 B Specification Requirements, % Min	Max
Aluminum								
Carbon	.19	.18	.22	.20	.14			.30
Chromium	.03	.08	.02	.03	.10			.40
Copper	<.02	.28	.02	<.02	.14			.40
Manganese	.99	.83	.77	.63	.72		.29	1.06
Molybdenum	<.01	.04	<.01	<.01	.06			.15
Nickel	<.02	.17	.02	.02	.14			.40
Niobium								
Phosphorus	.010	.005	.012	.011	.004			.035
Silicon	.23	.25	.25	.16	.22		.10	
Sulfur	.006	.021	.016	.004	.005			.035
Titanium								
Vanadium	<.01	<.01	<.01	.03	<.01			.08

Remarks: Complete: Sample(s) meet specifications

MIL-P-24691/1 refers to ASTM-A106 for chemical requirements.

JAN. 30 1996
Code 134.1 analyst, D. Vincent 155054
D. Vincent

Code 134.1 reviewer
B Smith 152487
1/30/96

Distribution: C/138 Weld Engr
SCHELTENS

CARBON STEEL DESTRUCTIVE TEST RESULTS

FEB. 5 1996

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 96PSO0966

Job order 8134590001001
Submit shop C/138 Weld Engr
Submit ship Code 138
Test Tensile, Lab Proc. 005
Num samples 2
Description SQUARE BUTT WELD QUAL 2" SC

Date received 960122
Specification MILP24691/1
Composition 1
Branch 134.6
Trace number PPCS-2,PPCS-4

TWO PIPES (PPCS-2,PPCS-4) WERE TENSILE TESTED AS REQUESTED BY C/138. THE PIPE SPECIFICATION IS MIL-P-24691/l (ASTM A106). THE WELDMENT SPEC. IS MIL-E-23765,70S2. THE RESULTS ARE AS FOLLOWS:

	PPCS -2	PPCS-4	REQUIRED PIPE	REQUIRED WELD
BREAKING LOAD(lbs)	109,600	110,200		
TENSILE STRENGTH(psi)	73,500	72,000	60,000 psi min	70,000 psi min
FRACTURE LOCATION	PIPE	**PIPE**		
ELONGATION (%)	45	**46**	**22 min**	**22min**

Remarks:

Complete: Sample(s) meet specifications

N. Doll, 152427
Nancy Doll 2/5/96
Operator (C/134.6) Date

A.K. Ruddebral 2/5/96
Reviewer (C/134.6) Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

"The person designated to sign for an action verifies, based On personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements. " Attachment 15

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 96 PS01371

Job order	8134590001001	Date received	960130
Submit shop	C/138 Weld Engr	Specification	MIL STD 248
Submit ship	Code 138	Composition	CARBON STEEL
Test	Multiple Tests	Branch	134.6
Num samples	6		
Description	ROOT BENDS, FACE BENDS AND MACROS		

TWO MACROS WERE EXAMINED AND EVALUATED IN ACCORDANCE WITH THE REQUIREMENTS OF Mil-STD-248C AND FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.6

TWO FACE AND TWO ROOT BEND SPECIMENS WERE TESTED AND EVALUATED IN ACCORDANCE WITH Mil-STD-248C AND FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.3.1

Remarks: PIPE SPECIFICATION: Mil-P-24691/l TYPE 1.
WELD FILLER: Mil-E-23765,70S2

Complete: Sample(s) meet specifications

A. Greene, 163115 A M Greene	2/6/96	[signature]	2/6/96
Operator (C/134.6)	Date	Reviewer (C/134.6)	Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

" The person designated to sign for an action verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements. " Attachment 15

STAINLESS STEEL DESTRUCTIVE TEST RESULTS

DEC. 6 1995

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 95PS15340

Job order: 8134590001001
Submit shop: C/138 Weld Engr
Submit ship: Code 138
Metals test: Tensile, Lab Proc. 005
Num samples: 2
Description: SQUARE BUTT WELD QUAL 2"SCH 80

Date received: 951205
Specification: MILP24191/3
Composition: 304
Branch: Metallurgy C134.6
Trace number: PPSS 1 & 2

	Ultimate Tensile Strength (PSI)	INFO ONLY Yield Strength @ 0.2% (PSI)	INFO ONLY Elongation @ FRACTURE (%)	FRACTURE LOCATION
001	93,000	45,500	65	ADJACENT TO WELD IN HAZ
002	91,500	46,200	70	ADJACENT TO WELD IN HAZ

Weld metal - Mil-E-19933/308L requirement:
75,000 min na 35 min na
Pipe base metal - Mil-P-24691/3 -- ASTM A312 requirement:
75,000 min 30,000 min 35 min

TWO TENSION SPECIMENS WERE TESTED IN ACCORDANCE WITH AWS B4.O AND MEET THE REQUIREMENTS OF MIL-STD-248C P-GRAPH 4.5.2.1.
The values provided for yield strength and elongation are not required and are apporximated using a non standard test method. The elongation was measured across the fracture.

Remarks:

Complete: Sample(s) meet specifications

A. Greene, 163115
A M Greene
Operator (C.134.6) 12/7/95 Date

Reviewer (C/134.6) 12/7/95 Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

"The person designated to sign for an action verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements."

DEC. 7 1995

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSurance OFFICE
Laboratory Division

Report 95PS15339

Job order 8134590001001
Submit shop C/138 Weld Engr
Submit ship Code 138
Test Multiple Tests
Num samples 8
Description SQUARE BUTT WELD QUAL 2“SCH

Date received 951205
Specification MIL-STD-248,ANS B
Composition
Branch 134.6
Trace number PPSS 3

1. TWO FACE BEND AND TWO ROOT BEND SPECIMENS TESTED AND EVALUATED TO MIL-STD-248C WERE FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.3.1

2. TWO ROOT BEND SPECIMENS WERE SUBJECTED TO PRACTICE E OF ASTM A262 AND SUBSEQUENTLY TESTED AND EVALUATED TO MIL-STD-248C WERE FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.3.1

3. TWO MACRO-ETCH SPECIMENS WERE PREPARED AND EVALUATED TO MIL-STD-248C WERE FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.6

Remarks: REFERENCE TENSION TEST REPORT 95PS95PS15340

Complete: Sample(s) meet specifications

A. Greene, 163115 12/7/95 Operator (C/134.6) Date	12/11/95 Reviewer (C/134.6) Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

"The person designated to sign for an action verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements."Attachment 16

MONEL DESTRUCTIVE TEST RESULTS

FEB. 6 1996

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 96PS01671
AMEND. #l

Job order	9138040140000	Date received	960202
Submit shop	C/138 Weld Engr	Specification	MIL-STD-248C
Submit ship	Code 138	Composition	MONEL
Test	Tensile, Lab Proc. 005	Branch	134.6
Num samples	2	Trace number	PPNC-2 & 3
Description	SQUARE BUTT WELDING PROD 2"		

TWO PIPES (PPNc-2,PpNC-3) WERE TENSILE TESTED AS REQUESTED BY c/138.

HE PIPE SPECIFICATION IS MIL-T-1368. THE WELDMENT SPEC. IS MIL-E-21562,

N 60. THE RESULTS AREC AS FOLLOWS:

	PPNC-2	PPNC-3	REQUIRED	
BREAKING LOAD(lbs)	88,100	87,100	PIPE & WELD	
TENSILE STRENGTH(psi)	84,000	81,000	70,000 psi min	
ELONGATION (%) "*"	22	22	35	30

THE LOCATION OF THE FRACTURES IN BOTH OF THE SAMPLES WERE DIAGONAL ACROSS HE WELD.

Remarks: AMENDMENT #1 DUE TO INCORRECT TRACE

Complete: FOR INFORMATION ONLY ------ "*"

N. Doll, 152427
Nancy Doll 2/7/96
Operator (C/134.6) Date

Reviewer (C/134.6) 2/7/96 Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

"The person designated to sign for an action verifies, based on personal observation, and certifies by his/her signature that the action has been performed in accordance with the specified requirements." Attachment 17

FEB. 6 1996

PUGET SOUND NAVAL SHIPYARD
QUALITY ASSURANCE OFFICE
Laboratory Division

Report 96 PS01673

Job order	9138040140000	Date received	960202
Submit shop	C/138 Weld Engr	Specification	MIL-STD-248
Submit ship	Code 138	Composition	
Test	Multiple Tests	Branch	134.6
Num samples	6	Trace number	PPNC-1
Description	SQUARE BUTT WELD PROD BENDS		

TWO MACRO SPECIMENS WERE PREPARED AND EVALUATED IN ACCORDANCE WITH Mil-STD-248C AND WERE FOUND To MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.6.

TWO FACE AND TWO ROOT BEND SPECIMENS WERE TESTED AND EVALUATED IN ACCORDANCE WITH Mil-STD-248C AND WERE FOUND TO MEET THE REQUIREMENTS OF PARAGRAPH 4.5.2.3.1.

Remarks: PIPE SPECIFICATION: Mil-T-1368
WELD FILLER: Mil-E-21562, RN60

Complete: Sample(s) meet specifications

A. Greene, 163115 A M Greene 2/6/96 Operator (C/134.6) Date	[signature] 2/6/96 Reviewer (C/134.6) Date

Distribution: C/138 Weld Engr, SCHELTENS 6-8808

"**The person** designated to sign for an action verifies, based on personal observation, and certifies .by his/her signature that the action has been performed in accordance with the specified requirements." Attachment 17

PSNS WELDING DATA SHEET # 123

TITLE	GTAW OF CARBON STEEL (CFE) SQUARE BUTT PIPE JOINT USING PULSE PURGE
JOINT DESIGN	SQUARE BUTT (SEE FIGURE 1) 0.125" MAX. GAP
POSITIONS QUALIFIED	ALL POSITIONS
PIPE WALL THICKNESS RANGE ...	0.100" TO 0.250"
BASE MATERIAL	CARBON STEEL (S-1)
FILLER MATERIAL .... (FOR SEAL OR COVER PASSES)	MIL-70S-2, 70S-3, 70S-4
TUNGSTEN ELECTRODE	1/16" AND 3/32" DIA., 2% THORIATED 90° BLUNT FOR SEAL AND ROOT PASS 4/1 TAPER FOR COVER PASS, SEE FIGURE 2
TUNGSTEN EXTENSION/CUP SIZE	1/2" MAX. EXTENSION WITH #7 CUP
TORCH GAS / FLOW RATE	95% ARGON AND 5% HYDROGEN / 15 TO 20 CFH
PURGE GAS / FLOW RATE	ARGON (< 1% OXYGEN CONTENT) / 8 TO 12 CFH
PURGE TYPE AND PRESSURE	
SEAL AND COVER PASS	STRAIGHT, 0.0 TO 1.5 INCHES OF WATER
ROOT PASS	PULSE, 0.0 TO 2.5 INCHES OF WATER
EDGE PREPARATION......................	SAW CUT AND DEBURRED
BASE METAL CLEANING	STAINLESS STEEL WIRE BRUSHED AND EMERY CLOTHED 1" FROM JOINT, ISOPROPYL ALCOHOL CLEANED.
PREHEAT TEMPERATURE	60°F MIN.
INTERPASS TEMPERATURE	N0 MAXIMUM (< 200°F PREFERRED)
COOLING BETWEEN BEADS	FORCED AIR COOLING

OPERATIONAL DATA			
PIPE WALL THICKNESS	WELD LAYER	FILLER MATERIAL	USE DCSP AMPERAGE RANGE
0.100" TO 0.190"	SEAL*	1/16" DIA.**	50 TO 100
	ROOT	NONE	60 TO 110
	COVER	1/16", 3/32"	50 TO 90
0.191" TO 0.250"	SEAL*	1/16" DIA.**	50 TO 120
	ROOT	NONE	90 TO 150
	COVER	1/16", 3/32"	50 TO 110

* TACK WELD PIPE JOINT THEN SEAL WELD. BOTK TACK AND SEAL WELDS ARE CONSUMED BY THE ROOT PASS.

** FILLER MATERIAL IS USED ON SEAL IF GAP EXCEEDS 0.030". WIRE FEED 1 TO 3 INCHES PER MINUTE

TRAVEL SPEED: SEAL -3 TO 6 INCHES PER MINUTE
ROOT- 0.5 TO 1.5 INCHES PER MINUTE
COVER -1 TO 3 INCHES PER MINUTE

PSNS WELDING DATA SHEET # 523

TITLE	GTAW OF STAINLESS STEEL (300 SERIES CRES) SQUARE BUTT PIPE JOINT USING PULSE PURGE
JOINT DESIGN	SQUARE BUTT (SEE FIGURE 1) 0.125″ MAX. GAP
POSITIONS QUALIFIED	ALL POSITIONS
PIPE WALL THICKNESS RANGE ...	0.100″ TO 0.250″
BASE MATERIAL	300 SERIES CRES (S-8)
FILLER MATERIAL .... (FOR SEAL OR COVER PASSES)	1/16″ and 3/32″ DIA. OF ML-E-19933, SEE SELECTION CHART
TUNGSTEN ELECTRODE	1/16″ AND 3/32″ DIA., *2%* THORIATED 90° BLUNT FOR SEAL AND ROOT PASS 4/1 TAPER FOR COVER PASS, SEE FIGURE 2
TUNGSTEN EXTENSION/CUP SIZE	1/2″ m. EXTENSION WITH #7 CUP
TORCH GAS / FLOW RATE	95% ARGON AND 5% HYDROGEN/15 TO 20 CFH
PURGE GAS / FLOW RATE	ARGON (<1% OXYGEN CONTENT) / 8 TO 12 CFH
PURGE TYPE AND PRESSURE	
SEAL AND COVER PASS	STRAIGHT, 0.0 TO 1.5 INCHES OF WATER
ROOT PASS	PULSE, 0.0 TO 2.5 INCHES OF WATER
EDGE PREPARATION......................	SAW CUT AND DEBURRED
BASE METAL CLEANING	STAINLESS STEEL WIRE BRUSHED AND EMERY CLOTHED 1″ FROM JOINT, ISOPROPYL ALCOHOL CLEANED.
PREHEAT TEMPERATURE	60″F MIN.
INTERPASS TEMPERATURE	350″F MAX.
COOLING BETWEEN BEADS	FORCED AIR COOLING

OPERATIONAL DATA			
PIPE WALL THICKNESS	WELD LAYER	FILLER MATERIAL	USE DCSP AMPERAGE RANGE
0.100" TO 0.190"	SEAL*	1/16" DIA.**	35 TO 70
	ROOT	NONE	40 TO 100
	COVER	1/16", 3/32"	35 TO 80
0.191" TO 0.250"	SEAL*	1/16" DIA.**	50 TO 100
	ROOT	NONE	90 TO 130
	COVER	1/16". 3/32"	40 TO 110

* TACK WELD PIPE JOINT THEN SEAL WELD. BOTH TACK AND SEAL WELDS ARE CONSUMED BY THE ROOT PASS.

** FILLER MATERIAL IS USED ON SEAL IF GAP EXCEEDS 0.030", WIRE FEED 1 TO 3 INCHES PER MINUTE

TRAVEL SPEED: SEAL -3 TO 6 INCHES PER MINUTE
ROOT- 0.5 TO 1.5 INCHES PER MINUTE
COVER -1 TO 3 INCHES PER MINUTE

FILLER METAL SELECTION CHART

BASE METAL	304	304L	310	316	316L	321	347
304	308, #1	308, #1	308, #1	308, #1	308, #1	308, #1	308, #1
304L		308L	308, #1	308, #1	308L	308L	308L
310			310	316, #1	316, #1	308, #1	308, #1
316				316, #1	316, #1	308, #1	308, #1
316L					316L	316L	316L
321						347	347
347							347

#l LOW CARBON GRADES OF THESE FILLER MATERIALS MAYBE USED WHEN REGULAR GRADE FILLER MATERIALS ARE NOT AVAILABLE AT THE WORK SITE ELECTRODE STORAGE / HOLDING AREA.

PSNS WELDING DATA SHEET # 723

TITLE .... GTAW OF NICKEL COPPER (Nicu)
SQUARE BUTT PIPE JOINT USING PULSE PURGE

JOINT DESIGN .... SQUARE BUTT (SEE FIGURE 1) 0.125″ MAX. GAP

POSITIONS QUALIFIED . . . . ALL POSITIONS

PIPE WALL THICKNESS RANGE . . . 0.100″ TO 0.160″

BASE MATERIAL .... NICKEL COPPER (S-42)

FILLER MATERIAL MIL-EN/RN60
(FOR SEAL OR COVER PASSES)

TUNGSTEN ELECTRODE . . . . 1/16" AND 3/32" DIA., 2% THORIATED
90° BLUNT FOR SEAL AND ROOT PASS
4/1 TAPER FOR COVER PASS, SEE FIGURE 2..

TUNGSTEN EXTENSION/CUP
SIZE .... 1/2" MAX. EXTENSION WITH #7 CUP

TORCH GAS / FLOW RATE . . . . 95% ARGON AND 5% HYDROGEN/15 TO 20 CFH

PURGE GAS /FLOW RATE . . . . ARGON (<1% OXYGEN CONTENT) / 8 TO 12 CFH

PURGE TYPE AND PRESSURE .
SEAL AND COVERPASS STRAIGHT, 0.0 TO 1.5 INCHES OF WATER
ROOT PASS .... PULSE, 0.0 TO 2.5 INCHES OF WATER

EDGE PREPARATION . . . . SAW CUT AND DEBURRED

BASE METAL CLEANING . . . . STAINLESS STEEL WIRE BRUSHED AND EMERY CLOTHED 1" FROM JOINT, ISOPROPYL ALCOHOL CLEANED.

PREHEAT TEMPERATURE . . . . 60°F MIN.

INTERPASS TEMPERATURE . . . . 350°F MAX.

COOLING BETWEEN BEADS . . . . FORCED AIR COOLING

OPERATIONAL DATA			
PIPE WALL THICKNESS	WELD LAYER	FILLER MATERIAL	USE DCSP AMPERAGE RANGE
0.100" TO 0.160"	SEAL*	1/16" DIA.**	50 TO 90
	ROOT	NONE	60 TO 110
	COVER	1/16", 3/32"	50 TO100

* TACK WELD PIPE JOINT THEN SEAL WELD. BOTH TACK AND SEAL WELDS ARE CONSUMED BY THE ROOT PASS.

** FILLER MATERIAL IS USED ON SEAL IF GAP EXCEEDS 0.030″, WIRE FEED 1 TO 3 INCHES PER MINUTE

TRAVEL SPEED: SEAL -3 TO 6 INCHES PER MINUTE
ROOT- 0.5 TO 1.5 INCHES PER MINUTE
COVER -1 TO 3 INCHES PER MINUTE

CARBON STEEL SQUARE BUTT AMI SETTINGS

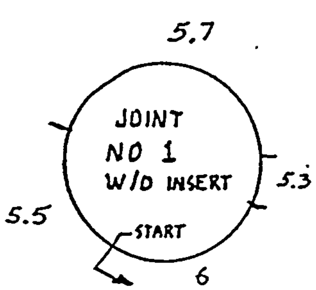
SQUARE BUTT AMI SETTINGS

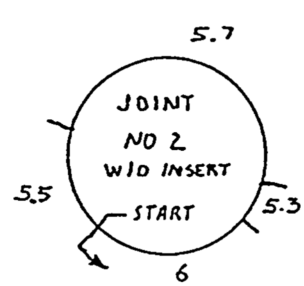
MATERIAL TYPE CARBON STEEL   PIPE SIZE & SCH 3" SCH 40   WALL 0.216"

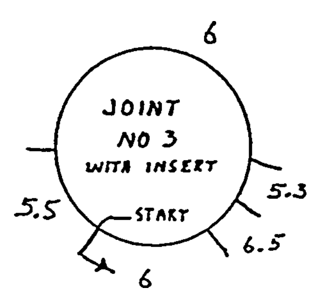
JOINT NO.	PRI AVC	BCK AVC	PRI AMPS	BCK AMPS	OSC AMPL	EXC TIME	PRI WIRE	BCK WIRE	OUT DWL TIME	IN DWL TIME	PRI PLS TIME	BCK PLS TIME	TVL SPD	AVC RESP
1	10.3	-	155	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
2	10	-	155	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
3	10	-	155	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
4														
5														
6														
7														
8														
9														
10														

NOTES :

1. **Unless otherwise noted, all welding will be done in the horizontal fixed position.**
2. **Unless otherwise noted, travel direction will be counter clockwise**
3. **The travel speed was adjusted as welding progressed to compensate for the changing weld position. The varying travel speeds for each weld joint are documented on their respective figures below. If' a primary amperage change was made, it was also documented on the respective figure.**







STAINLESS STEEL SQUARE BUTT AMI SETTINGS

SQUARE BUTT AMI SETTINGS

MATERIAL TYPE CRES PIPE SIZE & SCH 3" SCH 40 WALL 0.216"

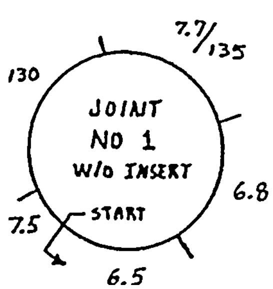
JOINT NO.	PRI AVC	BCK AVC	PRI AMPS	BCK AMPS	OSC AMPL	EXC TIME	PRI WIRE	BCK WIRE	OUT DWL TIME	IN DWL TIME	PRI PLS TIME	BCK PLS TIME	TVL SPD	AVC RESP
1	10	-	140	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
2	10	-	130	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
3	10	-	130	45	-	-	-	-	-	-	0.4	0.4	NOTE 3	2
4														
5														
6														
7														
8														
9														
10														

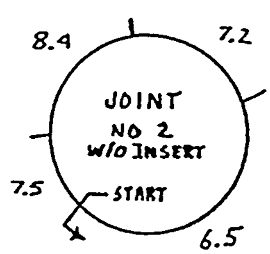
NOTES :

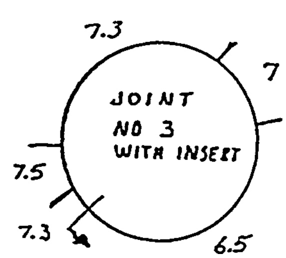
1. Unless otherwise noted, all welding will be done in the horizontal fixed position.

2. Unless otherwise noted, travel direction will be counter clockwise.

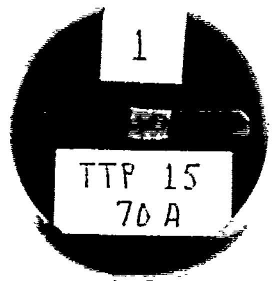
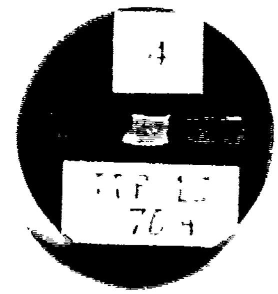
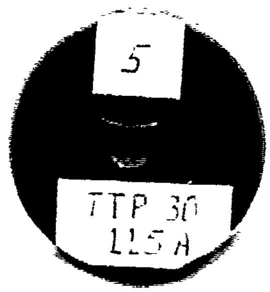
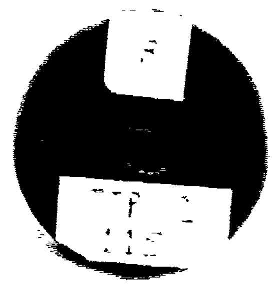
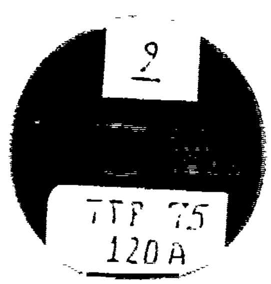
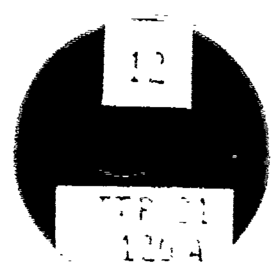
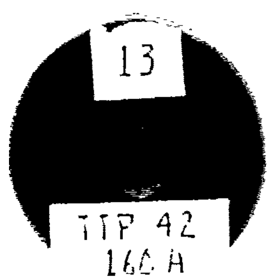
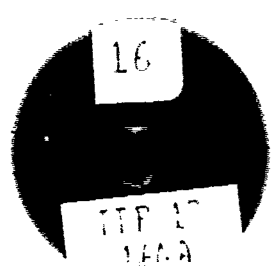
3. The travel speed was adjusted as welding progressed to compensate for the changing weld position. The varying travel speeds for each weld joint are documented on their respective figures below. if a primary amperage change was made, it was also documented on the respective figure.







Wall Fusion Cross Sections

	4-1 Taper Argon	Blunt 95-5
2" SCH 40 Cres 0.145		
2" SCH 80 Cres 0.218		
3" SCH 80 Cres 0.250		
3" SCH 80 Cres 0.300		

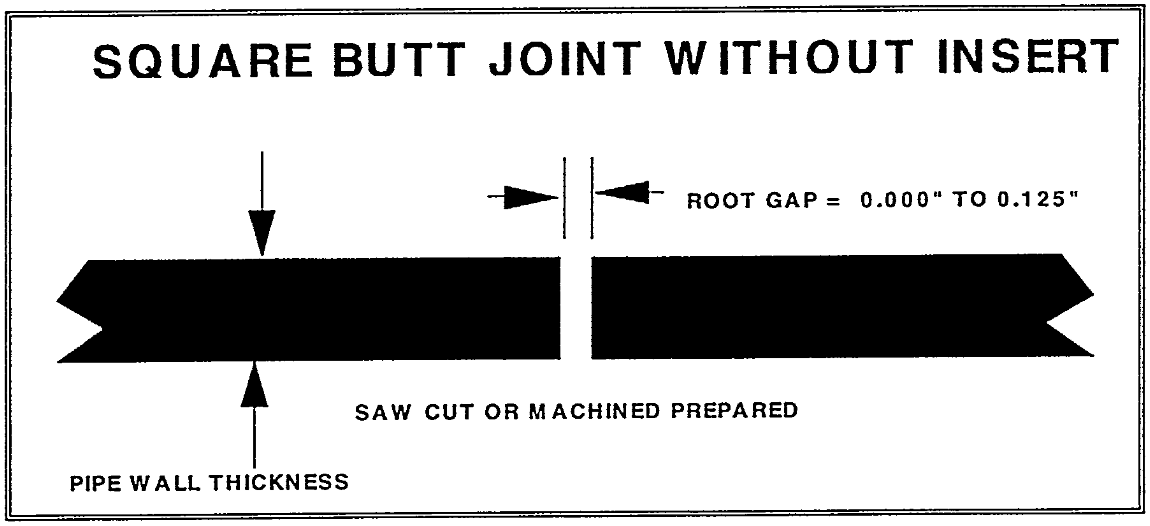


FIGURE 1

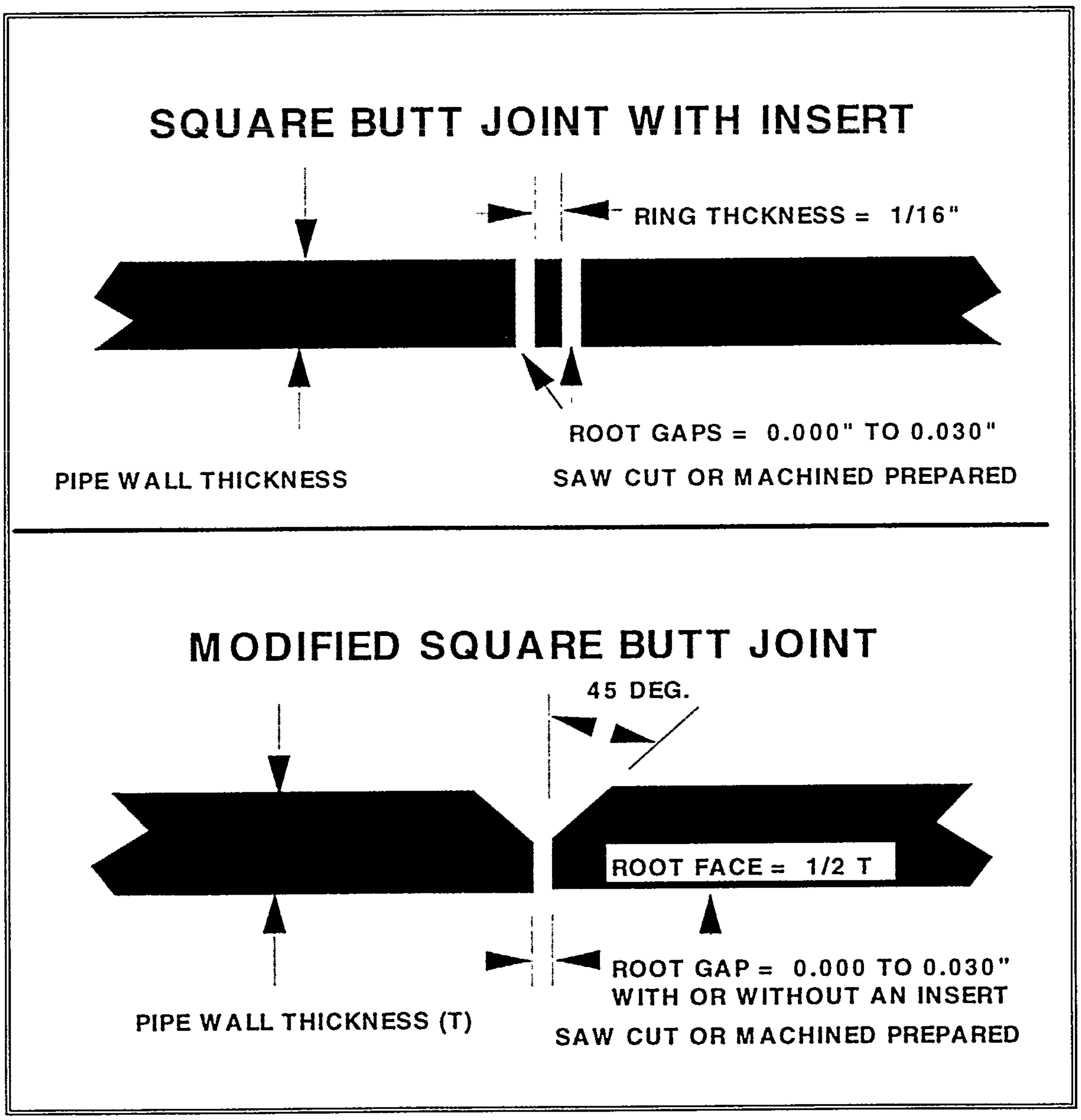


FIGURE 2

10 ° SQUARE BUTT JOINT DESIGN

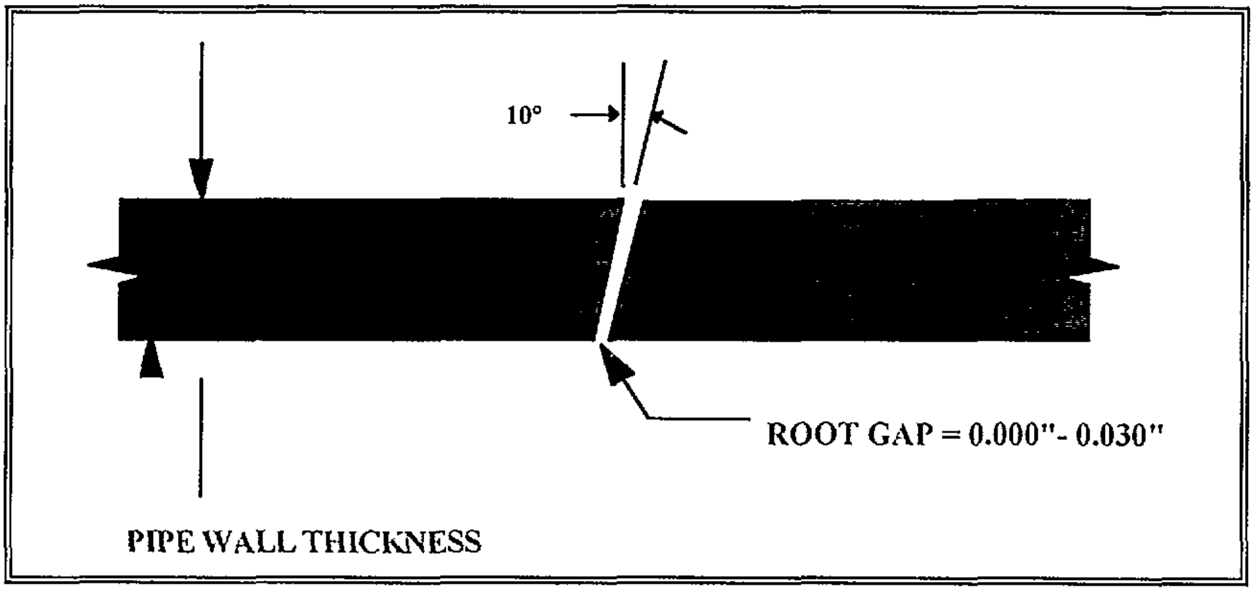


Figure 3

TUNGSTEN TIP SHAPES

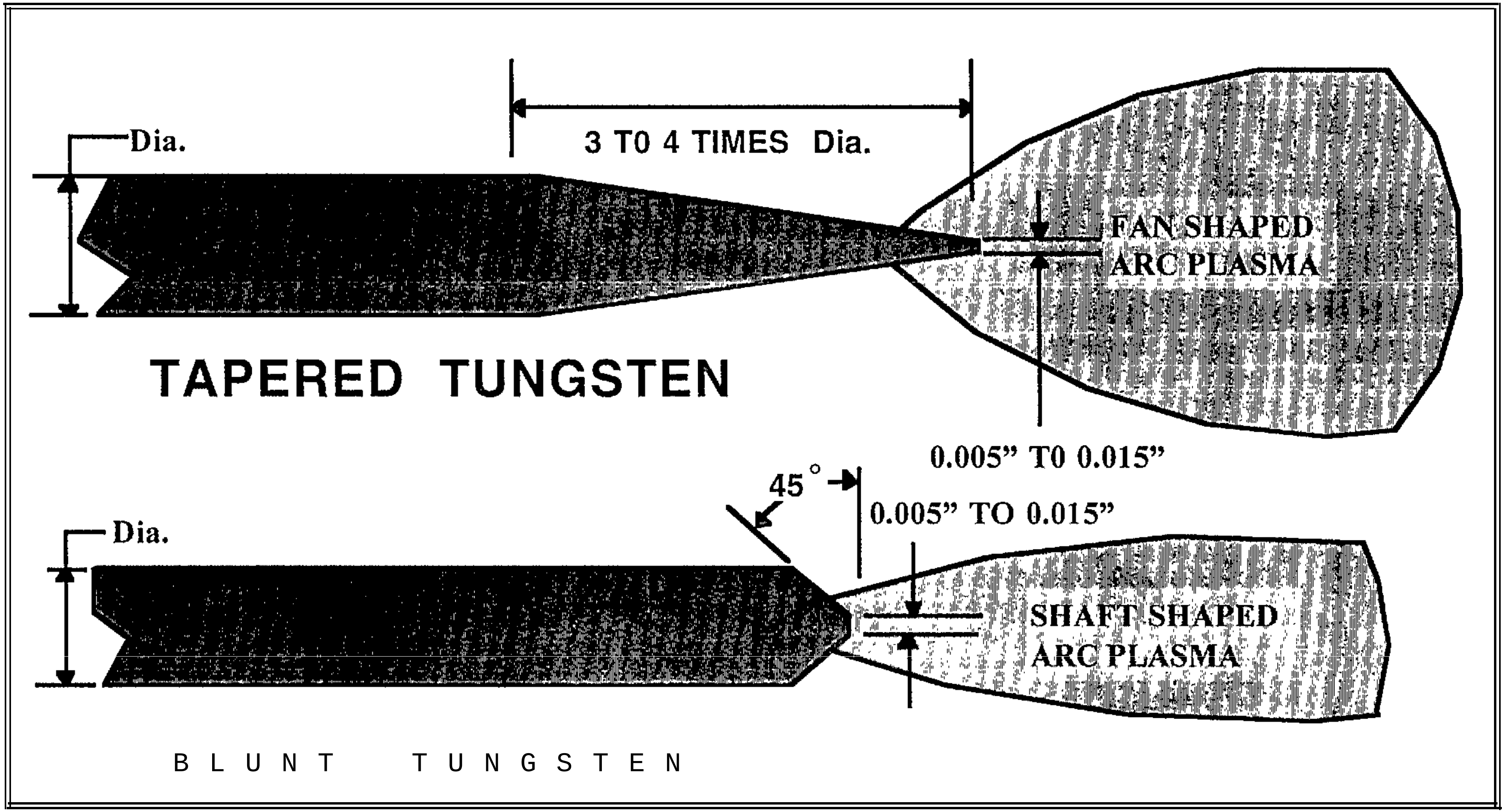


FIGURE 4

TYPICAL PULSE PURGE ARRANGEMENT

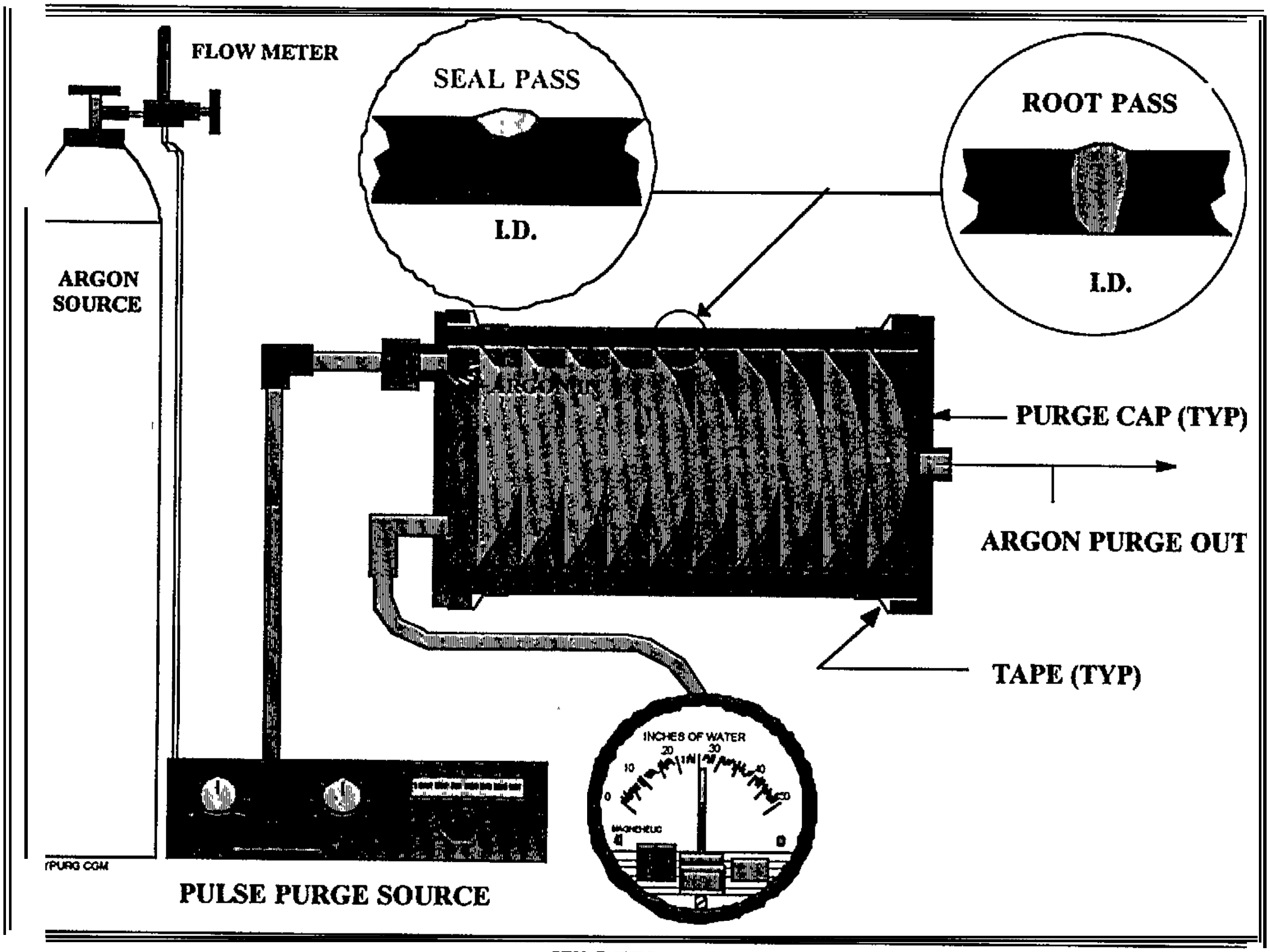
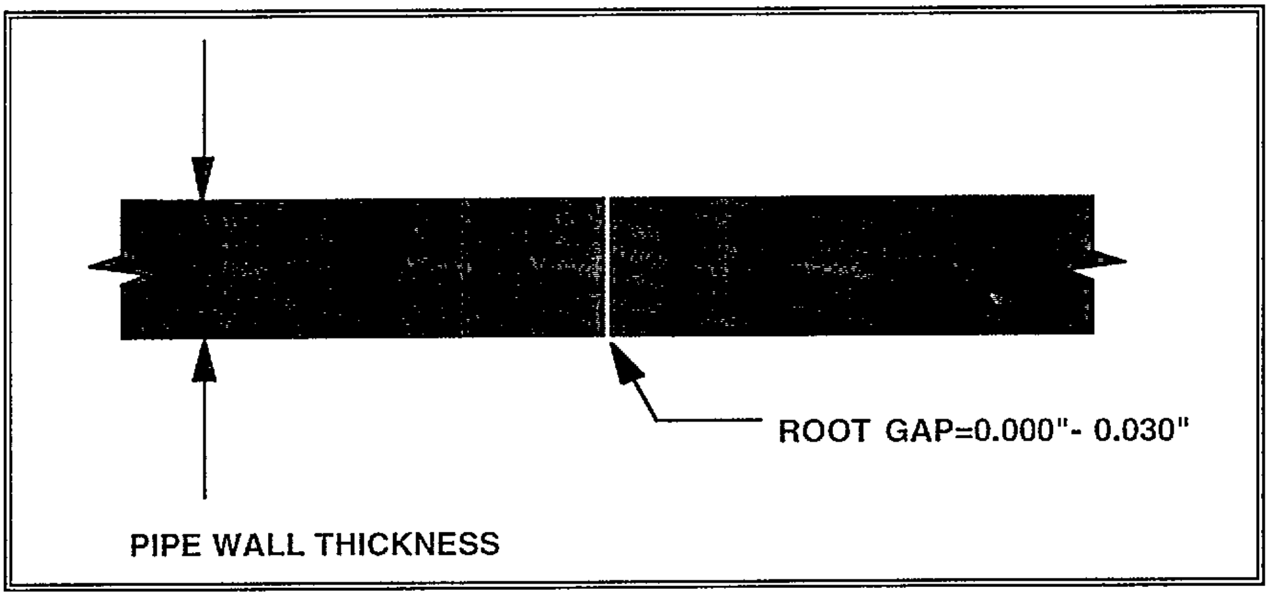
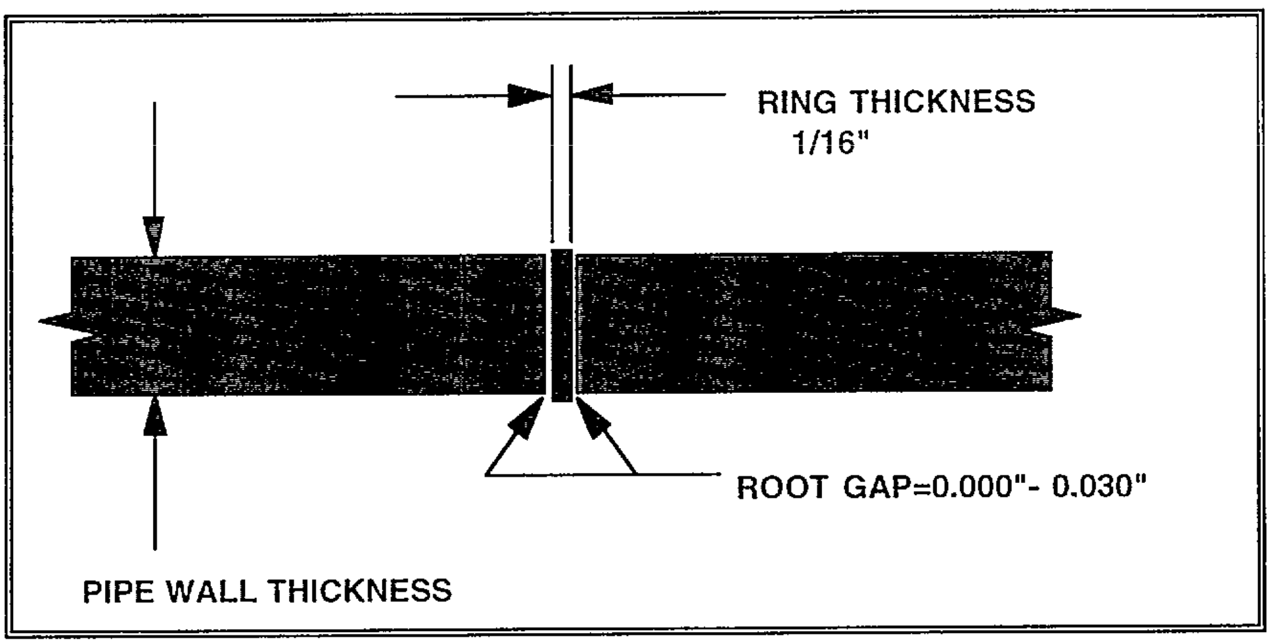


FIGURE 5

AUTOMATIC SQUARE BUTT JOINT DESIGN



JOINTS #1 AND # 2



JOINTS #3

FIGURE 6

TABLE I

MANUALLY WELDED SQUARE BUTT TEST MATRIX

PIPE SIZE IDENT	WALL	PIPE SIZE	STAINLESS STEEL			CARBON STEEL			CUNI		NICU	
			SA/PP (note 1)	SA/SP (note 2)	PA/SP (note 3)	SA/PP (note 1)	SA/SP (note 2)	PA/SP (note 3)	SA/PP (note 1)	SA/SP (note 2)	SA/PP (note 1)	SA/SP (note 2)
Cc	0.072"	1/2" Cls 700							45A/1.9[8]	50A/1.0[8]		
A	0.095"	1" Cls 700							50A/1.5[8]	50A/1.2[8]		
Aa	0.109"	1/2" Sch 40				50A/1.2		52A/3				
Dd	0.120"	1/2" Cls 3300							55A/1.8[8]	55A/1.0[8]		
Y	0.125"	5" Cls 200							80A/1.7	note 7		
Ff	0.130"	2" Cls 700										
C	0.133"	1" Sch 40	52A/1.2	56A/0.10	55A/3	56A/1.2	56A/.01	55A/3				
Bb	0.147"	1/2" Sch 80	60A/1.2		60A/3						90A/2.9	
E	0.154"	2" Sch 40	65A/1.4[4]	67A/0.01	67A/3			67A/3			95A/1.8	
W	0.165"	3" Cls 700							115A/1.3	note 7		
F	0.179"	1" Sch 80	65A/1.4	66A/0.01	66A/3						note 7	
Ee	0.180"	1" Cls 3300							105A/1.3	note 7		
I	0.216"	3" Sch 40	100A/1.5[5]		90A/2	120A/2.0[5]	125A/.01	120A/3				
K	0.237"	4" Sch 40										
N	0.300"	3" Sch 80	115A/1.3[6]									
V	0.438"	3" Sch 160	note 7									

NOTES FOR "MANUALLY WELDED SQUARE BUTT TEST MATRIX"

1. Data in columns referencing this note relates to welds made with a Steady Arc (SA) constant current, Pulsing Purge (PP) and 95% Argon with 5% Hydrogen shielding gas (95/5). This column documents the weld amperage used (i.e. 52A) and the peak pulse pressure measured in "inches of water" (i.e. 1.2).

2. Data in columns referencing this note relates to welds made with a Steady Arc (SA) constant current, Steady Purge Flow (SP) and 95% Argon with 5% Hydrogen shielding gas [95/5). This column documents the weld amperage used (i.e. 56A) and the constant purge pressure used in "inches of water".

3. Data in columns referencing this note relates to welds made with a Pulsing Arc (PA) pulsing current, Steady Purge Flow (SP) and 95% Argon with 5% Hydrogen shielding gas (95/5). This column documents the average weld amperage used (i.e. 55A) and the Arc Pack 350 Pulse Control Program Number (i.e. 3). Program number 3 requires a peak amperage of 69 amps (peak time of .80 seconds and background time of .53 seconds) to average 55 amps.

4. This weld was made using a 1/16" square ended tungsten.

5. These settings were used on a weld that passed X-Ray and destructive testing.

6. These settings were used on weld joints that had a 45° bevel and a 0.200" root face. One used a flat insert and the other no insert.

7. Full penetration could not be achieved on this wall thickness.

8. This weld was made using a 1/16" 90° blunt tungsten.

9. Unless otherwise noted, all welds were made using a 3/32" 90° blunt tungsten.

10, All welding was done in the horizontal fixed position.

TABLE II

AMI SQUARE BUTT DATA CHART

	0.150" WALL			0.200" WALL			0.250" WALL			0.300" WALL		
	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3	Jt 1	Jt 2	Jt 3
STAINLESS STEEL				135/45 53-7	140/45 65-77	130/45 66-75	160/45 5-6	152/45 4-6.5	152/45 4-65	180/50 28-32		
CARBON STEEL				155/45 53-6	155/45 53-6	155/45 53-6						
COPPER NICKEL												
NICKEL COPPER												

NOTES:

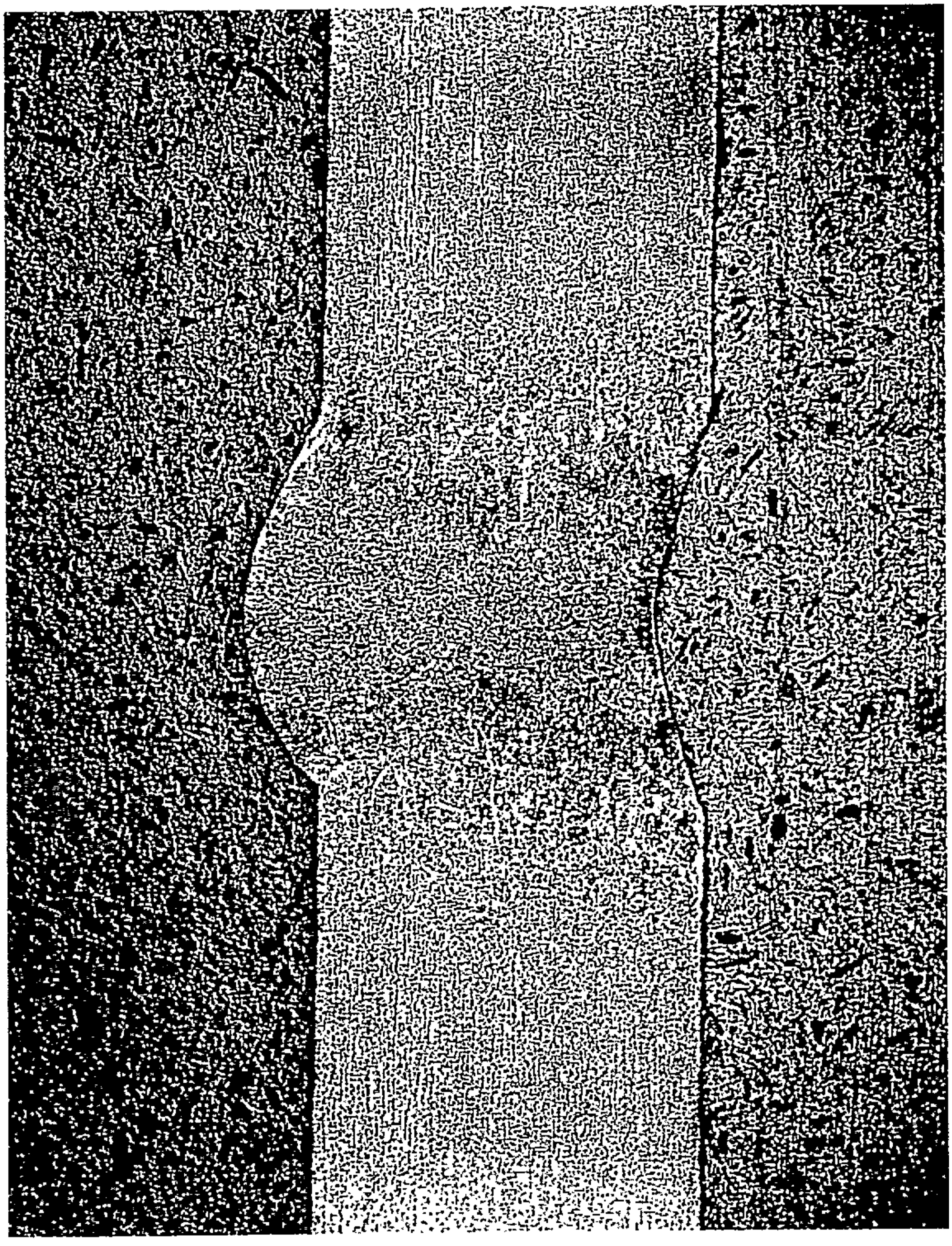
1, Each space on the chart represents a test weld.

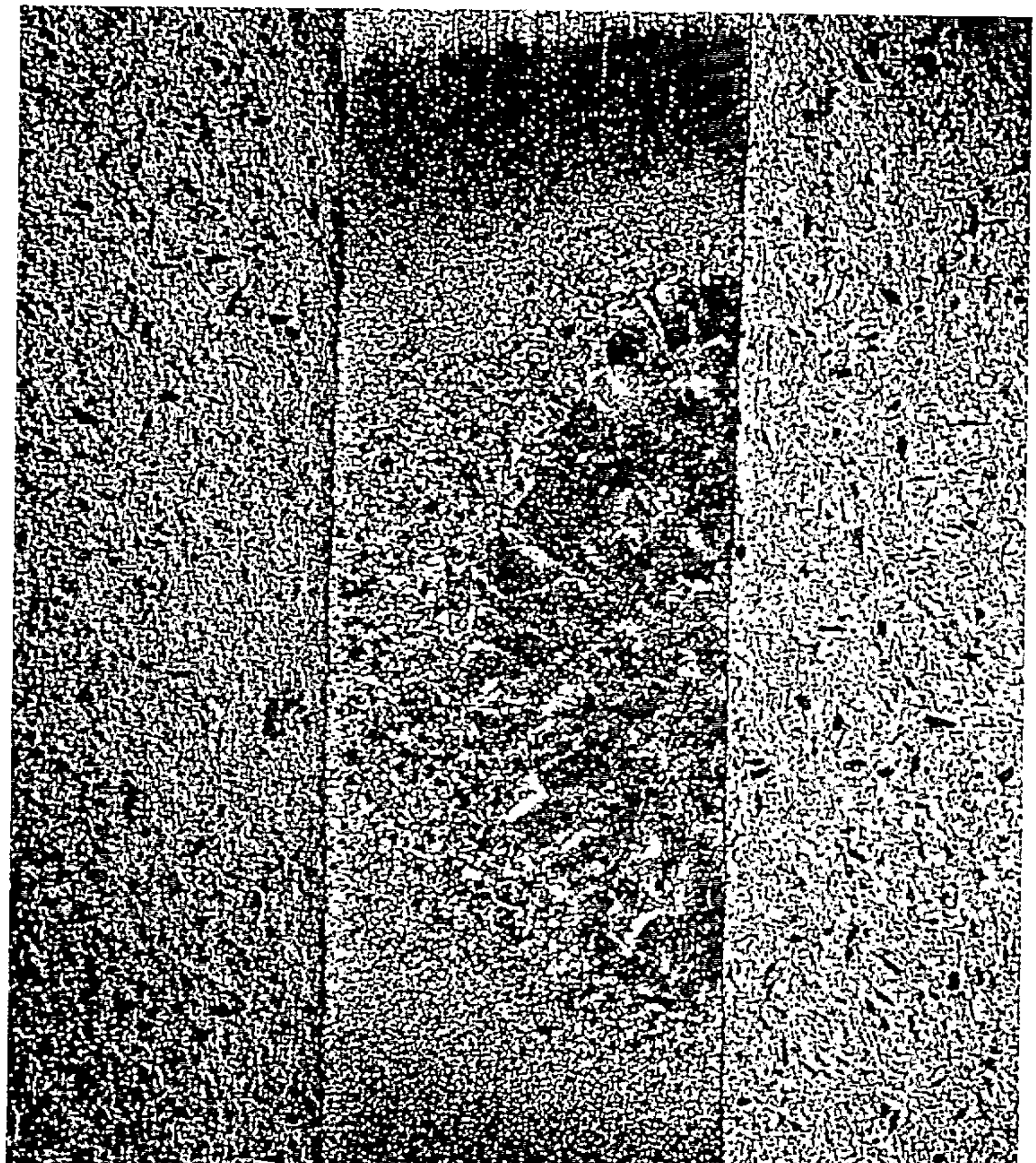
2. All Jt I & Jt 2 welds will be made on a saw cut square butt weld end prep, see Figure 9. Two consecutive welds will be made on this end prep to confirm repeatability of weld results.

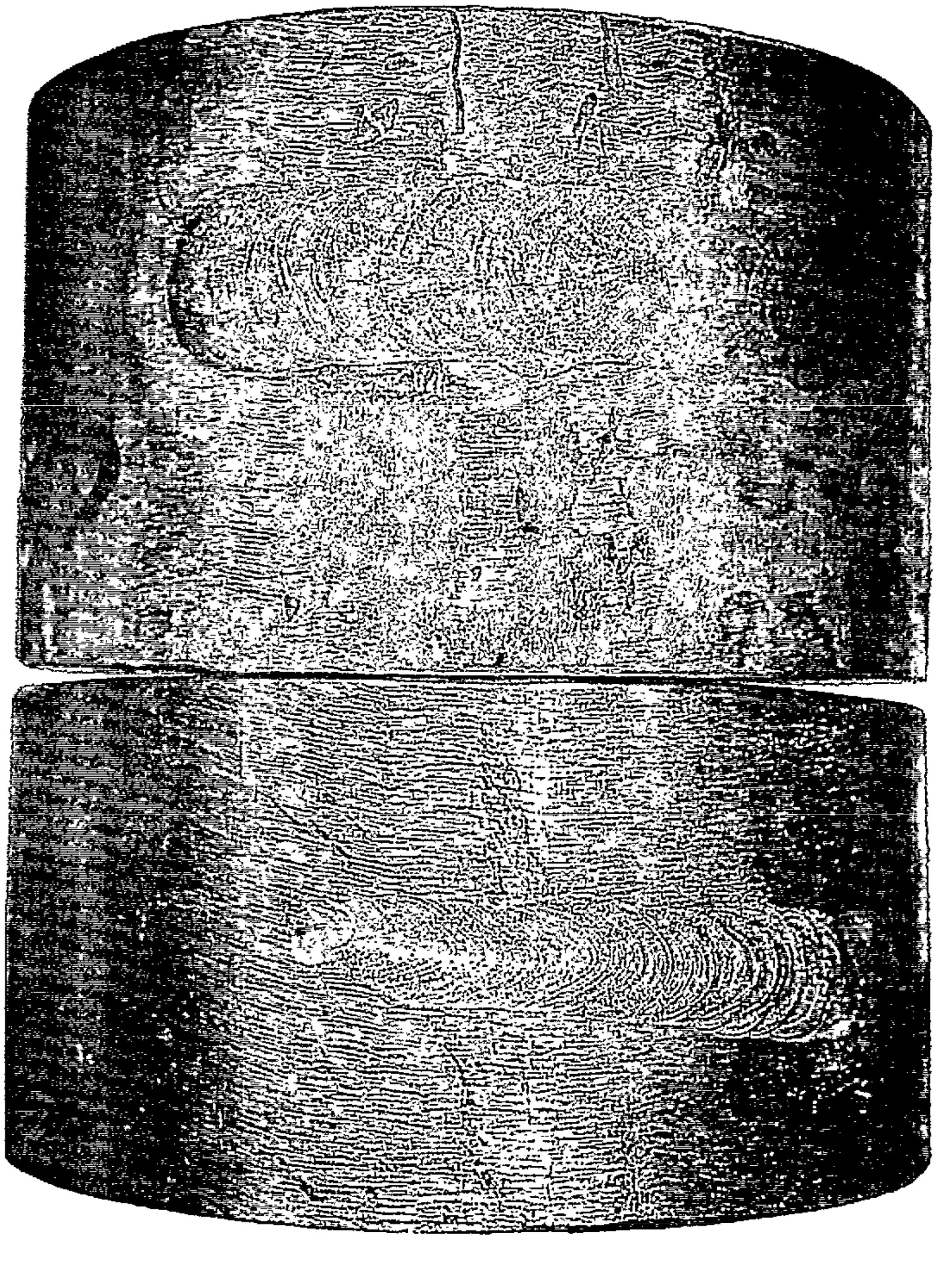
3. Jt 3 welds will be made on a saw cut square butt weld end prep with a 1/16″ thick flat consumable insert with a depth equal to or slightly greater than the wall thickness of the test pipe, see Figure 9.

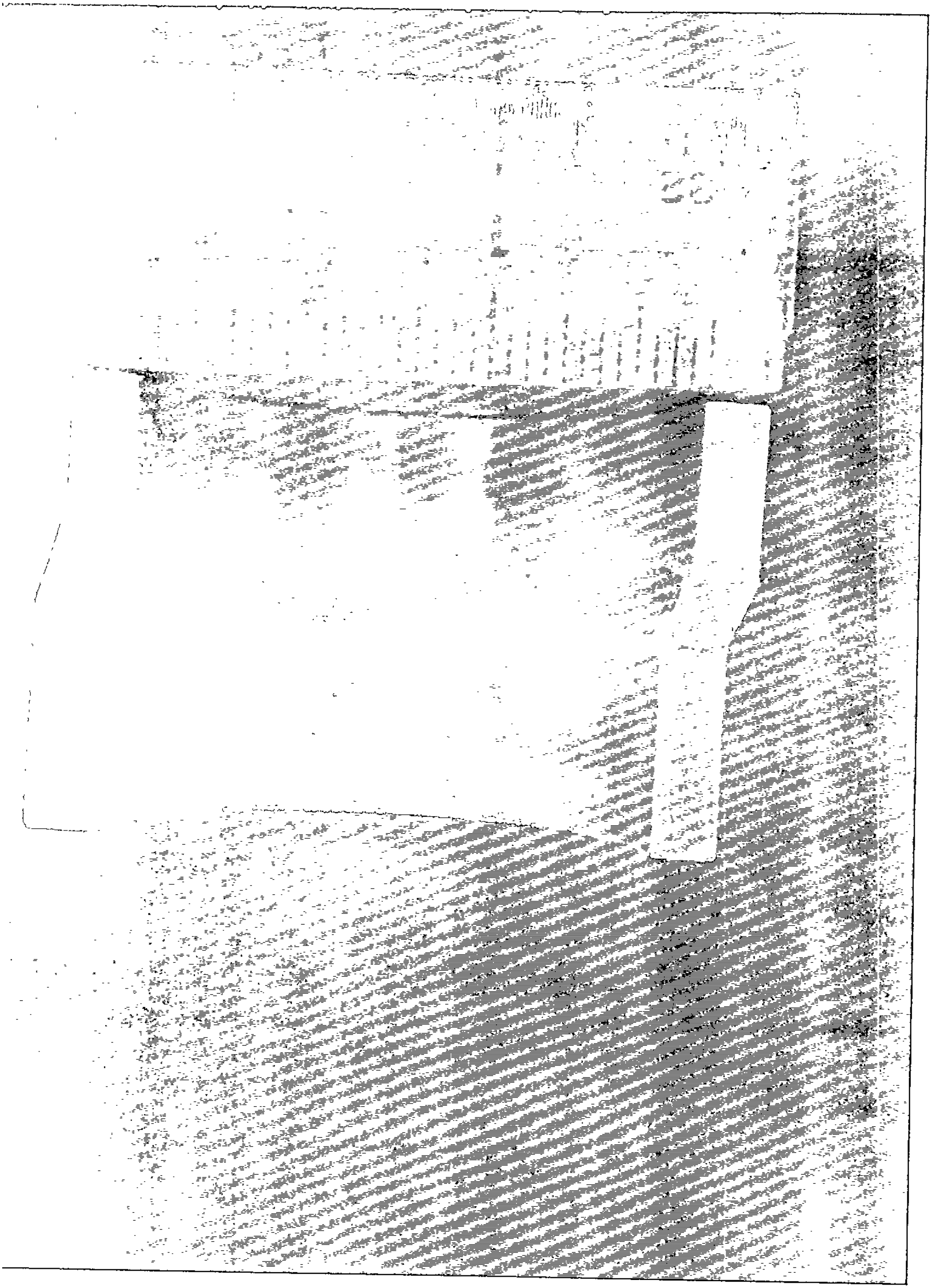
4. Data entries in each space will document welding results. Acceptable tests will li amperage (primary amps and background amps [i.e. 155/45]) and the travel speeds in per minute (slowest to the fastest [i.e. 5.3 -6]) that **were used.**

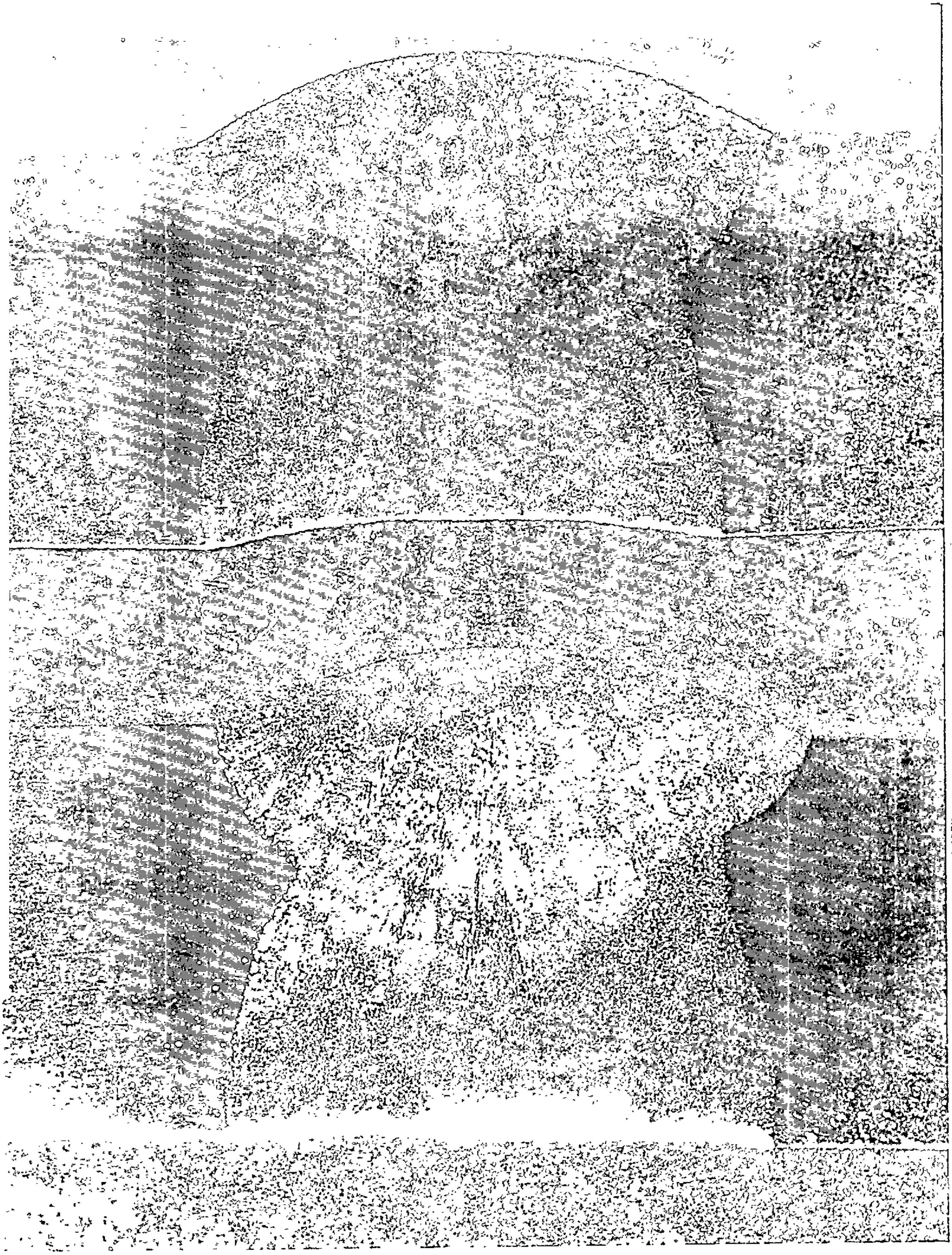
5. All welding will be done in the horizontal fixed position, unless otherwise noted.

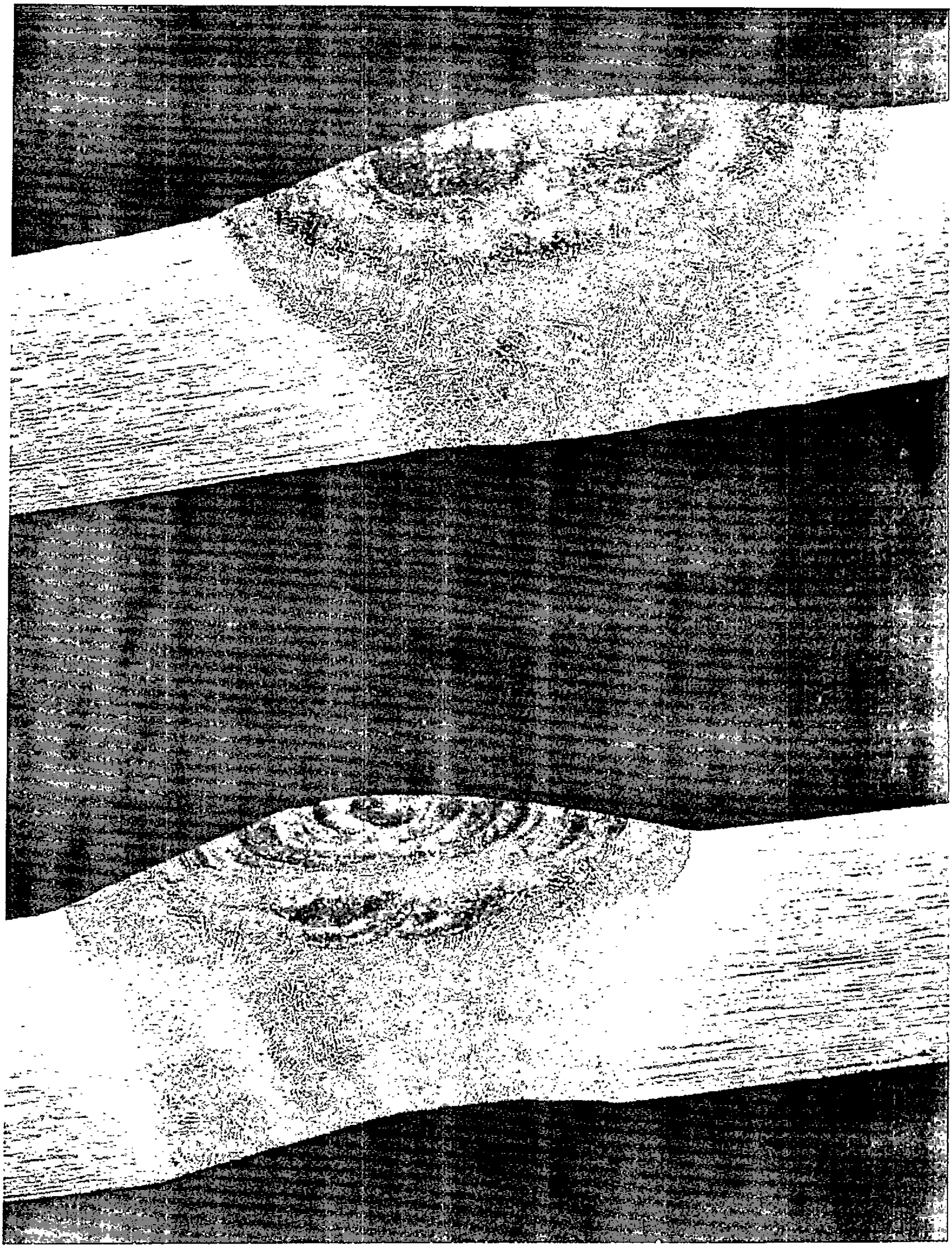












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